A new subgenus and five new species of Australian Glow-worms (Diptera: Keroplatidae: *Arachnocampa*)

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ABSTRACT

A new subgenus, *Arachnocampa* (*Lucifera*) subgen. nov., is described to include the Tasmanian species, *Arachnocampa tasmaniensis* Ferguson and the Mount Buffalo glow-worm, *Arachnocampa buffaloensis* sp. nov. The new subgenus is separated from the subgenera *Arachnocampa* (*Arachnocampa*) and *Arachnocampa* (*Campara*) by differences in wing venation. The subgenus *Arachnocampa* now includes only the New Zealand species *A. luminosa* (Skuse) which differs from species of *Lucifera* and *Campara* by its unusual method of vertical pupal suspension. The Australian species *A. tasmaniensis*, *A. flava* Harrison and *A. richardsae* Harrison are redescribed. Five new species are described: *A. buffaloensis* sp. nov. (Victoria) within the subgenus *Lucifera*; and *A. tropica* sp. nov. (north Queensland), *A. gippslandensis* sp. nov. (eastern Victoria), *A. otwayensis* sp. nov. (western Victoria) and *A. girraweenensis* sp. nov. (southeast Queensland/northern New South Wales) within the subgenus *Campara*. ❐ *troglophile, rainforest, threatened species, glow-worm, Keroplatidae, Arachnocampa, Lucifera, Campara.*

The genus *Arachnocampa* (Edwards 1924) contains species with bioluminescent larvae that are commonly known as glow-worms. Historically *Arachnocampa* contained four described species, three of which are endemic to Australia: *A. flava* Harrison from southeast Queensland (Perkins 1935; Harrison 1966); *A. richardsae* Harrison from New South Wales (Harrison 1966) and *A. tasmaniensis* Ferguson from Tasmania (Ferguson 1925). The fourth species, *A. luminosa* (Skuse 1890), is endemic to New Zealand. *Arachnocampa* are recognised as commercially valuable organisms due to the importance of glow-worms to tourism (Baker 2002). However, little was known about the insects around which this industry is based (Baker 2004). In Australia, *Arachnocampa* have been documented from several locations well separated from the known distributions of the three described species (Table 1). Until this study, these populations had been tentatively assigned to either *A. flava* or *A. richardsae* (e.g. Crosby 1978). The most recent reviews of the *Arachnocampa* taxonomic literature are by Pugsley (1983), Meyer-Rochow (2007) and Baker (2009).

The first description of an Australian glow-worm was of *A. tasmaniensis* from the Ida Bay Caves, Tasmania (Ferguson 1925). The description was based on the adult form, with a brief mention of larval biology. Other large colonies of glow-worms known from Numinbah in the Nerang Valley, Queensland and from New South Wales (Perkins 1935) were subsequently described as *A. flava* and *A. richardsae* respectively, and both species were placed in a new subgenus, *Campara* Harrison, separated from the Tasmanian and New Zealand species based on wing venation (Harrison 1966). McKeown (1935) noted the presence

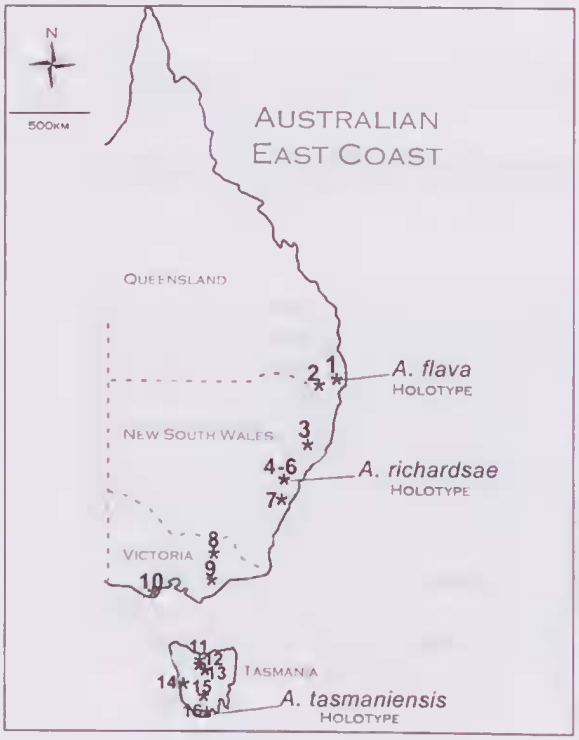

FIG. 1. Map of eastern Australia showing locations of published *Arachnocampa* sites based on literature surveys. Table 1 lists the names of each site. Three species of *Arachnocampa* have been described from these sites with many other sites documented but with no follow-up morphological identification until the present study.

FIG. 2. Map of eastern Australia showing the collection localities of specimens used for morphological examination. Regional groups are encompassed within circled areas. Site names are found in Table 2.

of *Arachnocampa* in the Otway Forest, Victoria. Crosby (1978) later tentatively identified this population as *A. richardsae*. However, this colony of *Arachnocampa* represents a new species, and is described here. Traditionally glow-worms have been included within the Mycetophilidae but following a review of the higher taxonomy of the Mycetophiloidea, *Arachnocampa* and other bioluminescent genera were placed in the family Keroplatidae (Matile 1981).

Arachnocampa are highly susceptible to desiccation and therefore require high humidity or direct contact with water within their habitat for survival (Richards 1960; Baker & Merritt 2003; Baker 2004). All published *Arachnocampa* sites in Australia are in rainforest, wet sclerophyll forest or limestone or granite boulder caves (Fig. 1, Table 1). Many of these records simply noted the presence of larvae and provided no additional information. Furthermore, the taxonomy of Australian *Arachnocampa* species in relation to their apparently widespread but patchy distribution is poorly understood, with the last taxonomic study by Harrison (1966). *Arachnocampa* display limited mobility, a shortened adult dispersal stage, and are reliant on specific high humidity environments for survival (Richards 1960; Baker 2004). Their primary reliance on habitats of ancient

TABLE 1. Published records of known *Arachnocampa* spp. locations in Australia illustrated in FIG. 1. Holotype locations from published descriptions indicated as follows: *A. flava* holotype *, *A. richardsae* holotype **, *A. tasmaniensis* holotype ***.

Aust. State	Location of *Arachnocampa* spp. colony	Reference
QLD	1. Natural Bridge, Springbrook National Park *	Perkins 1935, Harrison 1966
	2. River Cave, Girraween National Park	Finlayson 1982
NSW	3. Gloucester Cave, Gloucester	Harrison 1966, Eberhard & Spate 1995
	4. Grose Valley, Blue Mountains	Currey 1966, Harrison 1966
	5. Hazelbrook, Blue Mountains	Harrison 1966
	6. Newnes railway tunnel **	Harrison 1966
	7. Bundanoon	McKeown 1935
VIC	8. Underground River Cave, Mt Buffalo National Park	Crosby 1978
	9. Walhalla mine shafts, Walhalla	Harrison 1966
	10. Madsen's Track, Melba Gully State Park	Department of Conservation 1994
TAS	11. Loongana (Old tourist cave)	Geode 1967
	12. Gunns Plains Caves (Guns Plains Tourist Cave)	McKeown 1935, Geode 1967
	13. Mole Creek Caves (Marakoopa, Wet, Lynds and Westmoreland caves)	Geode 1967, Ferguson 1925
	14. Kelley Basin (small unnamed cave)	Geode 1967
	15. Florentine Valley and Junee Area (Cashion Creek, Growling Swallet and Junee Caves)	Geode 1967
	16. Ida Bay Caves (Entrance and exit caves) ***	Geode 1967, Ferguson 1925

Gondwanan origin, means that many populations are likely to have been fragmented in refugial habitat pockets for millions of years through natural contractions and expansions, with little to no chance of present day dispersal across large geographic boundaries (Baker 2004; Baker et al. 2008).

Australian glow-worm populations are under increasing pressure due to their restricted habitat range, critical habitat requirements, and increasing tourism popularity in these regions (Baker 2002, 2004). Therefore there is an urgent need for careful management to ensure the long-term sustainability of these species in Australia. Correct management guidelines can only be procured through a better understanding of the species present and, as such, this study was long overdue.

The taxonomic descriptions appearing in this paper were intended to be published prior to a molecular phylogenetic study of Australian glow-worms (Baker et al. 2008). However, the molecular study was published before the present descriptive paper, and the scientific names of the new taxa described here were inadvertently used in that paper. Baker et al. (2008) did not

TABLE 2. Map locations for Figure 2 with site names and codes used in descriptions. GPS coordinates for each site are listed in the text. All sites are epigean unless specified as a cave or man-made tunnel.

Map location Figure 2	Site Name	Site Code used in text
1	Mossman Gorge	NQLD1
2	Mt Lewis	NQLD2
3	Lamb Range National Park	NQLD3
4	Mt Hypipamee National Park	NQLD4
5	Bartle Frere Cave, Wooroonooran National Park	NQLD5
6	Bartle Frere stream	NQLD6
7	Mungalli Falls	NQLD7
8	Charmilllan walking trail, Tully Gorge State Park	NQLD8
9	Birthday Creek Falls, Paluma National Park	NQLD9
10	Tamborine Mountain	TAM1
11	Natural Bridge, Springbrook National Park (large overhang)	CALD1
12	Springbrook Plateau	CALD2
13	Springbrook National Park	CALD3
14	Lamington National Park	CALD4
15	South Bald Rock Cave, Girraween National Park	GIRRA1
16	Ramsey Creek Cave, Girraween National Park	GIRRA2
17	Mt Warning National Park	CALD5
18	Protestors Falls, Nightcap National Park	CALD6
19	Washpool National Park	NNSW1
20	New England National Park	NNSW2
21	Dorrigo National Park	NNSW3
22	Barrington Tops National Park	NNSW4
23	Gloucester Cave	NNSW5
24	Newnes Railway tunnel (man-made tunnel)	SNSW1
25	Waterfall Springs Conservation Park	SNSW2
26	Upper Kurrajong	SNSW3
27	Grand Canyon walk, Blue Mountains National Park	SNSW4
28	Bundanoon	SNSW5
29	"The Grotto" Fitzroy Falls National Park (large overhang)	SNSW6
30	Underground River Cave, Mt Buffalo National Park	BUFF1
31	Melba Gully State Park	WVIC1
32	Beauchamp Falls, Otway National Park	WVIC2
33	Hopetoun Falls, Otway National Park	WVIC3
34	Beauty Spot Reserve	WVIC4
35	Grey River Picnic area, Angahook-Lorne State Forest	WVIC5
36	She-oak Picnic area, Angahook-Lorne State Forest	WVIC6
37	Upper Yarra Valley mine tunnel	EVIC1
38	O'Shannassy Weir (man-made tunnel)	EVIC2
39	Britannia Creek Cave, State Forest	EVIC3
40	Shining Star Gold Mine, Warburton (tunnel)	EVIC4
41	Shiprock Falls Cave, Kilnkurth State Forest	EVIC5
42	Labertouche Cave	EVIC6
43	Walhalla Mine tunnel	EVIC7
44	Gunns Plains Caves	TAS1
45	Marakoopa Cave	TAS2
46	Sassafras Cave	TAS3
47	Derby Mine tunnel	TAS4
48	Francis Gully, Ida Bay	TAS5
49	Entrance ('Mystery Creek') Cave, Ida Bay	TAS6

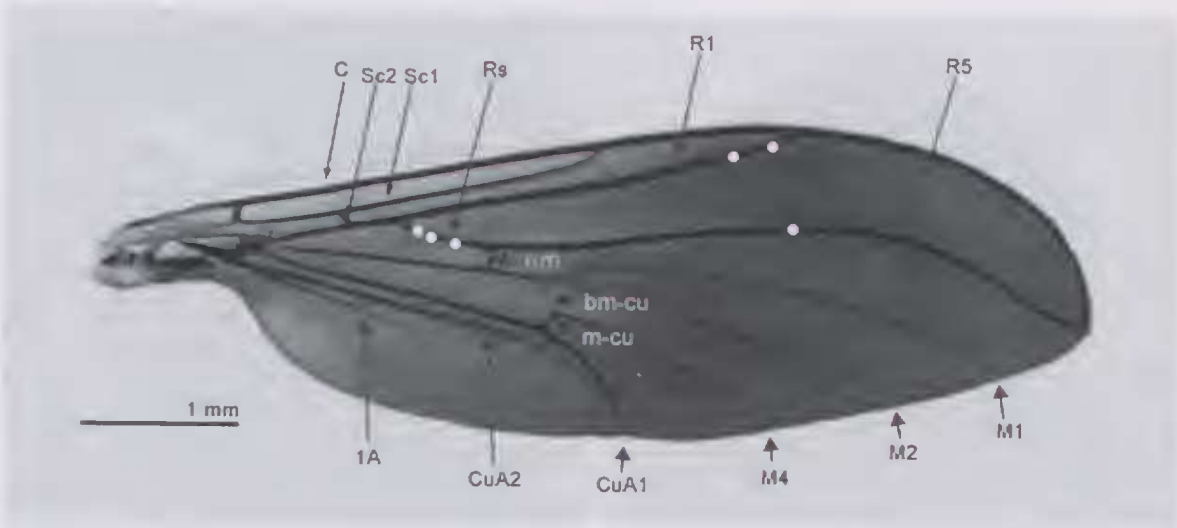

FIG. 3. Wing venation of *Arachnocampa* (dorsal view of right wing). Dots indicate the location of campaniform sensillae. C, costa; CuA1, anterior branch of cubitus; CuA2, posterior branch of cubitus; m-cu, posterior section of medial-cubital cross vein; M, media; r-m, radial-medial cross vein; R, radial vein; 1A, anal vein. Wing length measurements were taken from basal end to the wing apex.

fix holotypes for the new species, so the species names used there are not available (International Code of Zoological Nomenclature, 1999, Article 16.4). The subgenus name *Lucifera* as used by Baker et al. (2008) is also not available. It is a *nomen nudum* because the authors did not fix a type species (International Code of Zoological Nomenclature, 1999, Article 13.3). However, in order to preserve the link with the taxa referred to in the molecular paper (Baker et al. 2008), the same names are used here for the formal descriptions of the new subgenus and species.

MATERIALS AND METHODS

Taxon Sampling, Rearing and Labelling. *Arachnocampa* larvae were collected from 49 sites including many new locations (Fig. 2, Table 2). A GPS (eTrex®) was used to record site coordinates, however, due to dense

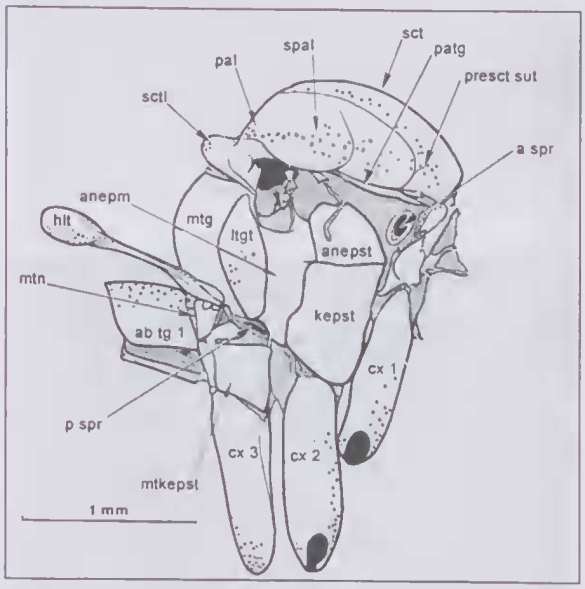

FIG. 4. Morphology and terminology of *Arachnocampa* thorax (revised from Matile 1990). ab tg 1, abdominal tergite 1; anepm, anepimeron; anepst, anepisternum; a spr, anterior spiracle; cx, coxa; hlt, haltere; keptst, katepisternum; ltgt, laterotergite; mtg, mediotergite; mtkepst, metakatepisternum; mtn, metanotum; pal, post alar region; patg, paratergite; p spr, posterior spiracle; presct sut, prescutal suture; sct, scutum; sctl, scutellum; spal, supra-alar region.

FIG. 5. Slide mounted *Arachnocampa flava* larval head capsule (dorsal view). ant, antennal stubb; l, labrum; s, stemmatal eye.

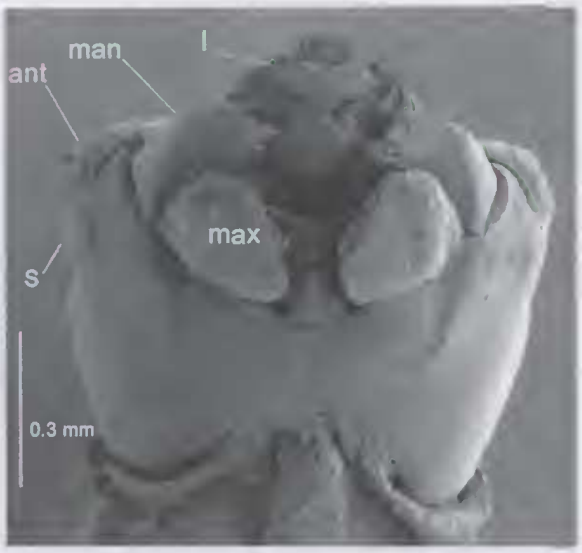

FIG. 6. Scanning electron micrograph (SEM) of *Arachnocampa flava* head capsule (ventral view). ant, antennal stubb; l, labrum; man, mandible; max, maxilla with maxillary teeth; s, stemmatal eye.

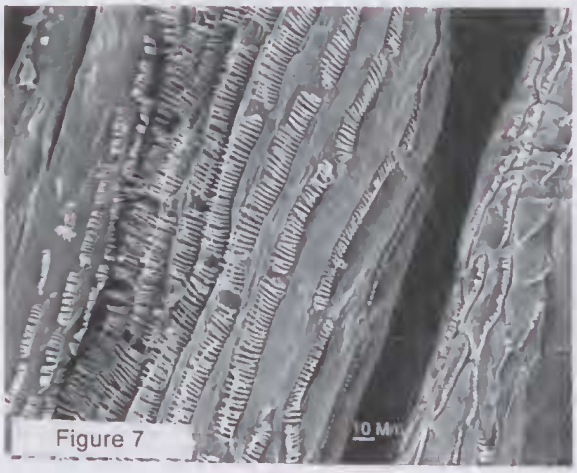

FIG. 7. SEM of setae on the distal end of *Arachnocampa flava* larva. These setae are used by larvae for movement.

FIG. 8. 'Tiger stripe' colouration of the *Arachnocampa* abdomen (each segment is lighter basally and darker apically).

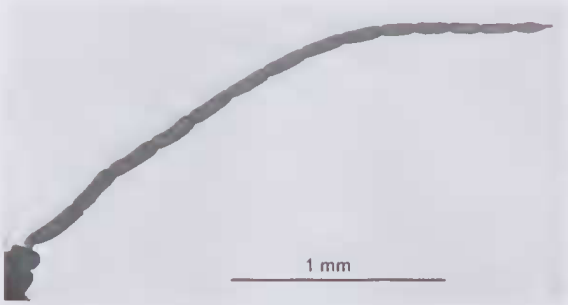

FIG. 9. Adult *Arachnocampa* antenna showing the progressive shortening of antennal segments from segments 1-13. Segment 14 is longer than 13, and is swollen, with a narrowed, apex.

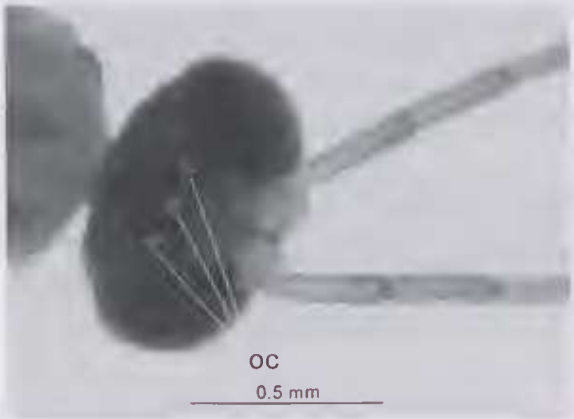

FIG. 10. Adult *Arachnocampa* head showing the placement of the ocelli on a raised ridge. The median ocellus faces anteriorly while the lateral ocelli are directed laterally.

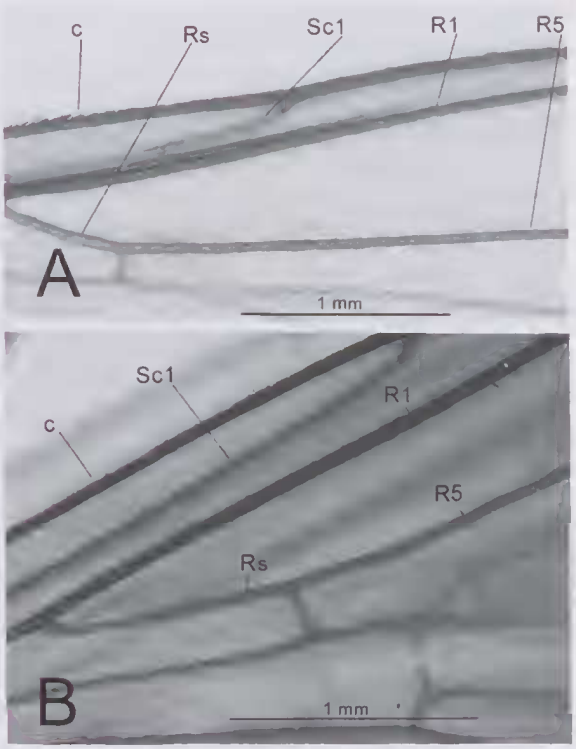

FIG. 11A-B. Wing vein setae placement in *Arachnocampa*. All species have setae on C (costal vein) and R_1 and R_5 (B), whilst *A. buffaloensis* also has setae on Sc_1 (A).

rainforest coverage the Geoscience Australia website was used to obtain GPS coordinates for some localities (http://www.ga.gov.au/map/names/). Specimens were sent live on ice to the University of Queensland where they were placed in individual containers for rearing to adulthood following methods outlined in Baker & Merritt (2003). Each examined specimen was labelled with the following data: state, locality, GPS coordinates, habitat, date and collectors. Holotype specimen are lodged in their corresponding state museums with paratypes distributed between the other state museums.

Terminology and Measurements. Morphological terminology follows McAlpine (1981) with minor modifications listed in the text. Terminology and measurements of wings and thoracic segments are illustrated in Figs 3-4. Measurements and terminology of the larval head capsule are indicated on Figs 5-6. Measurements listed in the text are taken primarily from the holotype, with paratype variation listed in parentheses or as ranges. In some instances, variation is listed from specific populations within a regional group, but mostly ranges are given separately for

males and females from entire regional groups. Measurements were taken from at least six to ten specimens where possible. If the number of available specimens of a species was low, all specimens were measured. Counts of the number of maxillary teeth were taken from the 5th instar exuviae after the onset of pupation or adult emergence. Larvae moult their exoskeleton and push it to the posterior end of the pupal case (Baker & Merritt 2003). This method was used to avoid potential differences in the numbers of maxillary teeth among different instars.

Preparation and Examination of Slide-Mounted Material. Specimens stored in 70% ethanol were progressively dehydrated (increasing by 10% concentration at each change) to 100% ethanol, cleared in 10% KOH on a heating block for 15-30 minutes, and washed in distilled water before being slide-mounted in glycerin or glycerin gel. Characters were examined using a Zeiss™ Stemi SV6 binocular dissecting microscope or Zeiss™ Axioscop binocular compound microscope. Pictures were taken using a colour 3CCD digital camera mounted onto the microscope. Measurements and digital images were taken using Scion Image V. 1.62. Scale bars and annotations were added in Adobe Photoshop 5.5. Scanning electron micrographs (SEM) were taken by Anthony O'Toole and Frederic Beaulieu, School of Life Sciences, University of Queensland. Images were taken on a Phillips XL20 at the centre for Microscopy and Microanalysis, University of Queensland.

Type Material. Holotypes were chosen as the specimen that best represented the species based on morphological characters. Type specimens of previously described species proved to be brittle and shrivelled, and of limited use for morphological examination. Therefore fresh specimens obtained from the type localities were used to prepare redescriptions.

Permits For Specimen Collection. Specimens included in this study were collected under the following scientific permits: Queensland, permit number W4/002525/00/SAA, New South Wales permit number B2111, Tasmania permit number 00093, Victoria permit number 10000827. Abbreviations for field collectors listed in the material examined sections are as follows: AM, Andrew McDowell; CB, Claire Baker; AR, Andrew Ridley; DM, David Merritt; ASH, Andrew Shek; JF, Josh Fartch; AS, Amanda Smith; SB, Stuart Baird.

Type Deposition. Type specimens of described species were borrowed from the Australian National Insect Collection (ANIC), Canberra and The South Australian Museum (SAM), Adelaide. Types have been deposited as per permit requirements, with holotypes deposited in their respective state insect collections and paratypes deposited across various collections as follows: Australian Museum (AM), Sydney; Museum Victoria (MV), Melbourne; Queensland Museum, (QM), Brisbane; Tasmanian Museum and Art Gallery (TM), Hobart; University of Queensland Insect Collection (UQIC), Brisbane.

SYSTEMATICS

CHECKLIST OF THE GENUS *ARACHNOCAMPA*.

The following taxonomic checklist is modified from Matile (1981). A new subgenus, *Lucifera*, is proposed to include *A. tasmaniensis* and *A. buffaloensis*. Four new species are allocated to the subgenus *Campara*, with the type species, *A. luminosa* in subgenus *Arachnocampa*.

FAMILY KEROPLATIDAE

SUBFAMILY ARACHNOCAMPINAE

Genus *Arachnocampa* (Edwards, 1924)

Arachnocampa Edwards, 1924: 177. Type species: *Bolitophila luminosa* Skuse, 1890 by original designation.

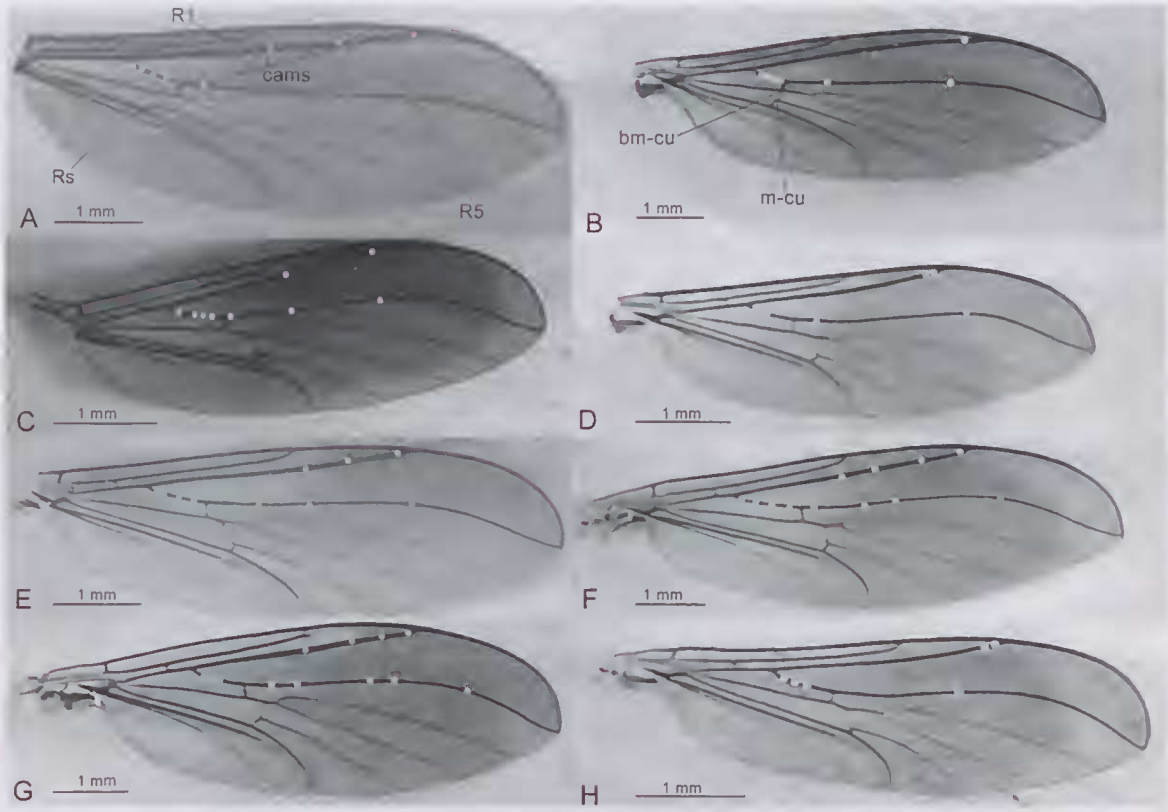

FIG. 12A-H. *Arachnocampa* spp. wings. A, *A. tasmaniensis*; B, *A. buffaloensis*; C, *A. tropica*; D, *A. flava*; E, *A. girraweenensis*; F, *A. richardsae*; G, *A. gippslandensis*; H, *A. otwayensis*. cams, campaniform sensillae.

Subgenus *Arachnocampa* Edwards

Arachnocampa Edwards, 1924: 177 (as genus). Type species: *Bolitophila luminosa* Skuse, 1890 by original designation.

Subgenus *Lucifera* subgen. nov.

tasmaniensis Ferguson, 1925: 487. Australia (TAS). Type species

buffaloensis sp. nov. Australia (VIC)

Subgenus *Campara* Harrison

Campara Harrison, 1966: 880. Type species: *Arachnocampa richardsae* Harrison 1966 by original designation.

flava Harrison, 1966: 880. Australia (Queensland)

richardsae Harrison, 1966: 881. Australia (New South Wales)

tropica sp. nov. Australia (Queensland)

girraweenensis sp. nov. Australia (Queensland/New South Wales)

otwayensis sp. nov. Australia (Victoria)

gippslandensis sp. nov. Australia (Victoria)

REDESCRIPTION OF *ARACHNOCAMPA* EDWARDS

DIAGNOSIS. Empodia and pulvilli absent. Radial sector originating far before middle of wing and far before tip of costa. R_4 absent. Larval head capsule as long as broad. Labrum hood-like. Larval mandibles longer than broad with prominent teeth. Larval antennae vestigial. Posterior abdominal segment of larva with papillae. Pupation taking place in larval web. Pupa not actively mobile, but upon disturbance

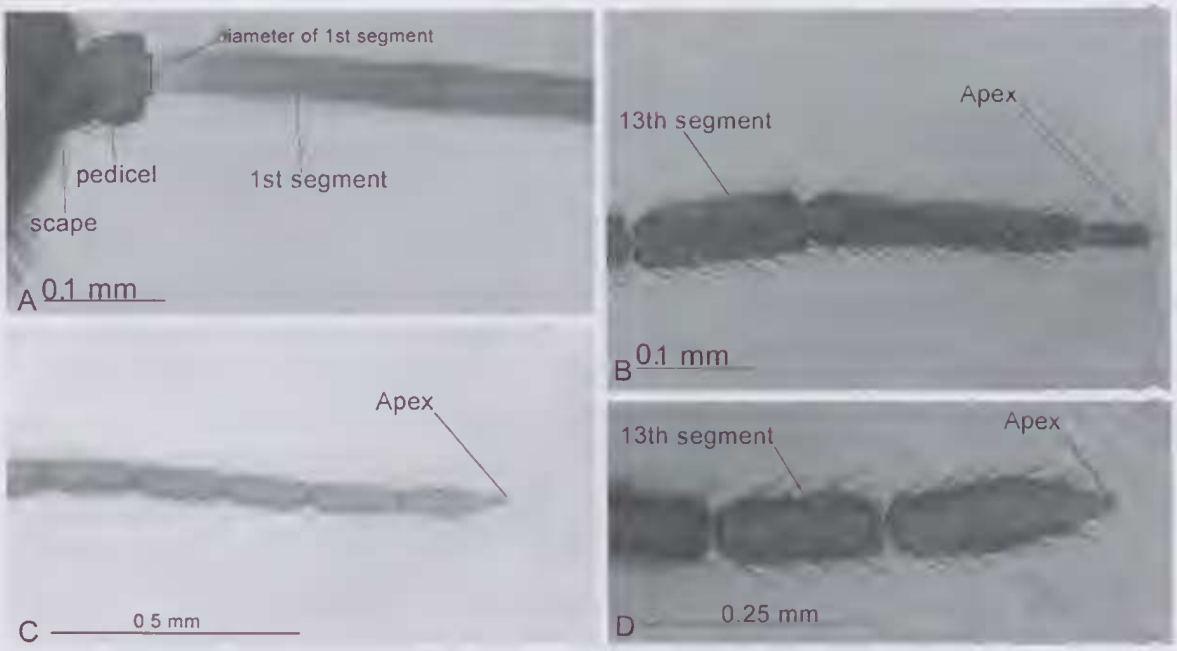

FIG. 13. Antennae of *Arachnocampa* spp. A, *A. tasmaniensis* antennal base indicating position at which diameter of 1st segment was measured; B, *A. tasmaniensis* male antennal apex. The apex of this species is elongate; C, *A. buffaloensis* female antennal apex; D, *A. richardsae* female antennal apex.

is capable of small movements within remains of larval snare.

Description. BIOLOGY: Larvae produce bioluminescence from posterior end. Larvae construct snares (webs) from silk and sticky mucous droplets in which they lie within a mucous tube. Snares consist of a number of silk 'fishing lines' with sticky mucous droplets for prey capture.

Morphology. Larval antenna vestigial and in the form of low hemispherical pale yellow protuberance (Figs 5-6). Larva with rows of fine setae at distal end (Fig. 7) and pair of large anal papillae. Larval mandibles with four apical teeth and one median tooth on inner surface (Fig. 6). Adult antennae with fourteen flagellar segments, longest segment at base, segments progressively shortening to 13th segment (Fig. 9); 14th segment longer than 13th, narrowing to a short, rounded apex. Front dark brown. Ocelli on prominent raised ridge facing anteriorly and laterally (Fig. 10); strong dark setae covering ridge. Face medium brown with thick cluster of setae over facial carina. Eyes covered with mat of fine, dark interommatidial hairs. Row of setae along lateral margins of scutum. Leg segments uniformly brown except lighter basal section of coxa. Hind legs darker. Legs covered in fine setae. Two apical tibial spurs on ventral side of mid and hind leg. One apical tibial spur on fore leg. Strong setae (quarter of length of ventral spurs) along tibiae and tarsi and clustered around dorsal apex of tibiae. Wing veins brown. Darker on costal (C), subcostal (Sc1) and radial veins (R). Strong dark setae on C, (setae on Sc1 in *A. buffaloensis* only, Fig. 11A) and R_1 and R_5 veins (Fig. 11B). Abdominal

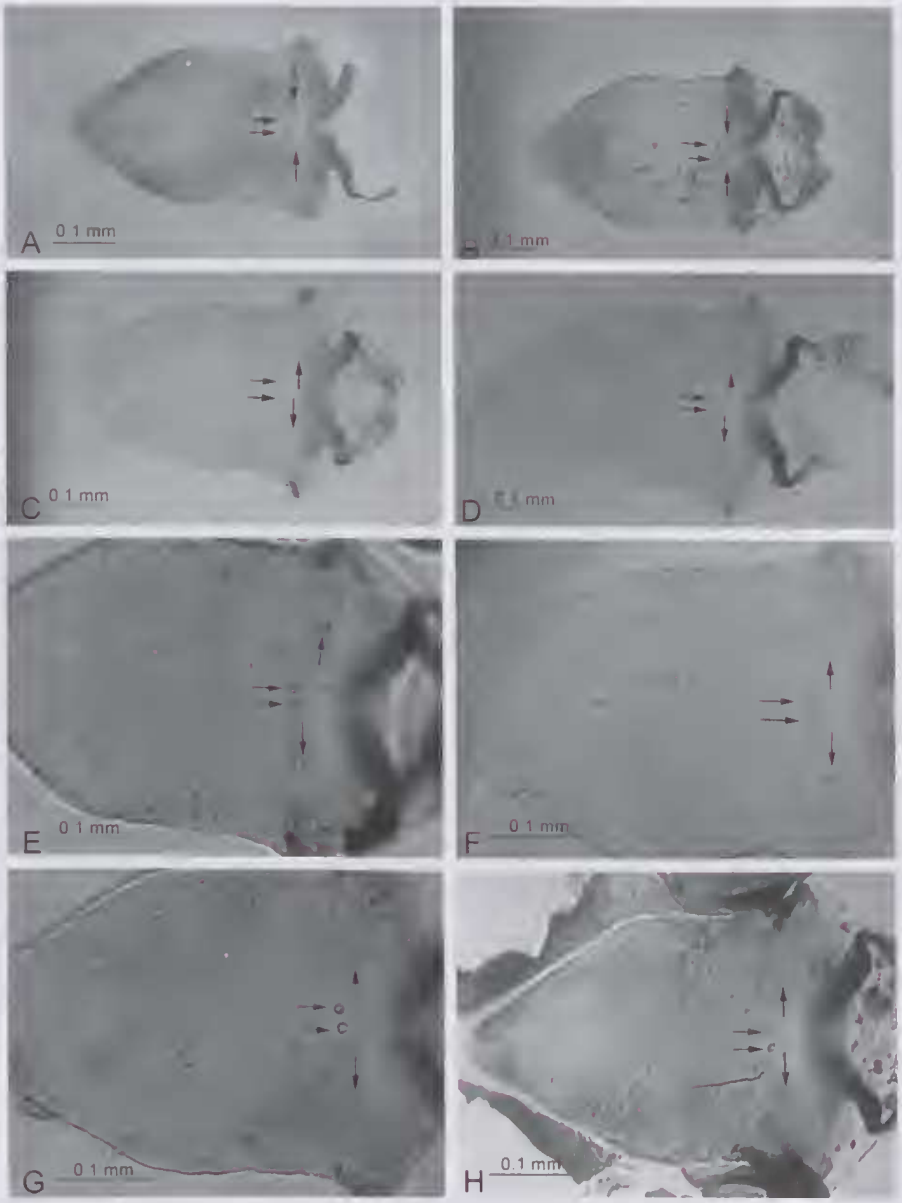

FIG. 14. *Arachnocampa* spp. larval sclerotised head plates indicating placement of campaniform sensillae (with arrows). This arrangement of the campaniform sensillae differentiates the subgenus *Campara* (C-H) from the subgenus *Arachnocampa* (A-B). A, *A. tasmaniensis*; B, *A. buffaloensis*; C, *A. tropica*; D, *A. flava*; E, *A. girraweenensis*; F, *A. richardsae*; G, *A. gippslandensis*; H, *A. otwayensis*.

segments 2-7 with tergites and sternites covered in black hairs. Abdominal segment 1 with tergite hairy, sternite with hairs on distal edge only. ♀ with more setae on basal abdominal segments than ♂. Eggs clearly visible through adult ♀ abdomen. All adult abdominal segments yellow to dark brown, darker at distal end of each segment, giving distinctive 'tiger stripe' colouration (Fig. 8).

KEY TO THE SUBGENERA OF *ARACHNOCAMPA* (MODIFIED FROM EDWARDS 1924)

1. Wing with m-cu cross vein basal to r-m cross vein; fore basitarsus equal to, or up to 1.3 times length of fore tibia; pupae suspended vertically; endemic to New Zealand . . *Arachnocampa (Arachnocampa)* Edwards
2. Wing with m-cu cross vein basal to r-m cross vein (Fig. 12A-B); fore basitarsus 1.55-2 times length of fore tibia; pupae suspended horizontally; endemic to Tasmania and Mt Buffalo, Victoria, Australia . . . . . *Arachnocampa (Lucifera)* subgen. nov.
3. Wing with m-cu cross vein distal to r-m cross vein (Fig. 12C-H); basal segment of fore tarsus 1.3-1.5 times length of fore tibia; pupae suspended horizontally; found in eastern Australia . . . . . *Arachnocampa (Campara)* Harrison

REDESCRIPTION OF SUBGENUS *ARACHNOCAMPA* BASED ON EDWARDS (1924)

Diagnosis. Adult wing with m-cu basal to r-m (Fig. 12A-B). bm-cu 0.72-1.6 times length of m-cu (Fig. 12A-B). bm-cu straight (Fig. 12A-B). Scape with full ring of setae around distal end. Larval head capsule with campaniform sensillae in block formation with setae (Fig. 14A-B). Larval malpighian tubules white (Fig. 15A-D). Pupae suspended vertically with one silk line connecting to thoracic region.

ARACHNOCAMPA (LUCIFERA) SUBGEN. NOV.

Arachnocampa (Lucifera) Baker et al., 2008 *nomen nudum*

Type species. *Arachnocampa tasmaniensis* Ferguson, 1925.

This study has supported Edward's (1924) division of *Arachnocampa* into two subgenera, *Arachnocampa* and *Campara*, based on the position of the m-cu vein. However, I have identified additional characters that further subdivide *Arachnocampa*. Consequently, I propose a new subgenus, *Lucifera*, for *A. tasmaniensis* Ferguson and *A. buffaloensis* sp. nov. *Lucifera* is distinguished from *Campara* by wing venation and sensillum pattern. The subgenus *Arachnocampa* is separated from *Lucifera* by the unique method of vertical pupal suspension of its now single constituent species, *Arachnocampa luminosa* (Skuse).

Diagnosis. Adult wing with m-cu basal to r-m (Fig. 12A-B). bm-cu 0.72-1.6 times length of m-cu (Fig. 12A-B). bm-cu straight (Fig. 12A-B). Scape with full ring of setae around distal end. Larval head capsule with campaniform sensillae in block formation with setae (Fig. 14A-B). Larval malpighian tubules white (Fig. 15A-D). Pupae suspended horizontally with one silk line connecting to thoracic region and another to the abdominal region.

Etymology. Lucifera, literally meaning 'light bringing', refers to the unique ability of *Arachnocampa* to produce light. It also has reference to the enzyme luciferase and substrate luciferin that produce the light in conjunction with adenosine 5'-triphosphate (ATP) and oxygen.

KEY TO SPECIES OF THE SUBGENUS *LUCIFERA*

1. Fore basitarsus 1.75-2 times length of fore tibia, endemic to Tasmania . . . . . *tasmaniensis* Ferguson
2. Fore basitarsus 1.55 times length of fore tibia, endemic to Mt Buffalo, Victoria . . . . . *buffaloensis* sp. nov.

FIG. 15. *Arachnocampa* spp. larvae (live whole mounts). A, *A. tasmaniensis* (epigean); B, *A. tasmaniensis* (cave); C, *A. tasmaniensis* (cave); D, *A. buffaloensis*; E, *A. tropica*; F, *A. flava*; G, *A. girraweenensis* (cave2); H, *A. girraweenensis* (cave1); I, *A. richardsae* (cave); J, *A. richardsae* (epigean); K, *A. gippslandensis* (cave); L, *A. gippslandensis* (cave). mt, malphigian tubules.

REDESCRIPTION OF SUBGENUS *CAMPARA* BASED ON EDWARDS (1924)

Diagnosis. Adult wing with m-cu distal to r-m (Fig. 12C-H). bm-cu 1.4-4.5 times length of m-cu (Fig. 12C-H). bm-cu curved. Scape with half ring of setae on ventral side of distal end. Larval head capsule with campaniform sensillae in line with setae rather than block formation (Fig. 14C-H). Larval malpighian tubules white (Fig. 15G, K) to light brown (Fig. 15H, I, J, L) to black (Fig. 15E-F). Pupae suspended horizontally with one silk line connecting to thoracic region and another to abdominal region.

KEY TO SPECIES OF THE SUBGENUS *CAMPARA*

To accurately distinguish species in this subgenus, all life stages are needed. Genetic data and mating trials clearly indicate them to be distinct species. Large geographic boundaries between species and no evidence of sympatric speciation mean geographic information is often the easiest way to distinguish these species.

1. 5th instar larva with 10 maxillary teeth on one side and 11 on the other (Fig. 16B, D)... 2
– 5th instar larva with 9 maxillary teeth on one side and 10 on the other (Fig. 16A, C)... 3

2. Larval malpighian tubules black (Fig. 15E). Adult laterotergite with 2-30 setae (Fig. 17C); bm-cu 1.7-2.5 times length of m-cu (Fig. 12C). Found in wet tropical rainforests of north Queensland ..... *tropica* sp. nov.
– Larval malpighian tubules white to light brown (Fig. 15G-H). Adult laterotergite with 0-5 setae (17E); bm-cu 1.8-4.5 times length of m-cu (Fig. 12E). Found in caves in Girraween National Park, south-east Queensland and rainforest in northern New South Wales (Washpool, Dorrigo and New England National Parks) ..... *girraweenensis* sp. nov.

3. Larval malpighian tubules black (Fig. 15F). Adult laterotergite with 1-4 setae; bm-cu 1.9-2.7 times length of m-cu (Fig. 12D). Found in isolated rainforest gullies in Kroombit Tops National Park and rainforest of the Mt Warning Caldera including northern New South Wales ..... *flava*
– Not with above combination of characters 4

4. Larval malpighian tubules pale to medium brown (Fig. 15I, J). Adult laterotergite with 0-21 setae; bm-cu 1.5-3 times length of m-cu (Fig. 12F). Found in rainforested regions of central to southern New South Wales (Blue Mountains, Bundanoon, Fiztroy Falls) ..... *richardsae* Harrison
– Not with above combination of characters. Adult with never more than 3 small setae on laterotergite. Found in rainforest areas in southern Victoria 5

5. Adult body length 10-12.2 mm; wing length 6.5-8 mm; ♀ antennal length 3.2-3.3 mm; bm-cu 1.75-2.6 times length of m-cu (Fig. 12G). Found in Gippsland rainforest and isolated cave systems of Victoria ..... *gippslandensis* sp. nov.
– Adult body length 6.5-8 mm, wing length 4.5-5.5 mm, ♀ antennal length 2-2.2mm; bm-cu 2.4-3.3 times length of m-cu (Fig. 12H). Found in rainforest west of Melbourne (including Otway National Park and Melba Gully and Angahook-Lorne State Parks) ..... *otwayensis* sp. nov.

Arachnocampa (*Lucifera*) *tasmaniensis* Ferguson, 1925

Arachnocampa tasmaniensis Ferguson, 1925: 487; Harrison, 1966: 879 (redescription).

Material Examined. HOLOTYPE ♂ (in copula with paratype ♀), bearing the label: 'Ida Bay caves, Arthur M. Lea, December, 1909. In total darkness fully 1/4 mile from entrance', condition: poor. Card mounted, both holotype ♂ and paratype ♀ missing antennae, legs and wings glued to card (SAM).

Other Material. TASMANIA, 3♂♂, 5♀♀, Mole Creek Karst National Park, Marakoopa cave, 41°35'S, 146°17'E, 17.i.2001, CB/DM, collected as larvae, reared to adults in incubator by CB, TAS2#1,2,3,7,9,11,16; 2♀♀, Sassafras cave, 41°34'S, 146°21'E, 1.x.2001, CB/AS, collected as larvae, reared to adults in incubator by CB, TAS3#3-4; 3♂♂, Francistown, property of Arthur Clarke, rainforest gully along stream, 43°18.5'S, 146°59.4'E, 16.i.2001, CB, collected as larvae, reared to adults in incubator by CB, TAS5#1-2,5; 5♂♂, 7♀♀, Ida Bay caves, Mystery Creek cave (Entrance cave), 43°27.7' S, 146°50.0'E, 16.i.2001, CB/DM, collected as larvae, reared to adults in incubator by CB, TAS6#1-2, 6-8, 12-14, 17-18, 22-23.

The following redescription and measurements are based primarily on ♂ TAS6#22, with other specimens measured for ranges and variation.

Diagnosis. Wing with m-cu located basal to r-m (Fig. 12A); bm-cu straight (not curved), angled backwards towards wing base and 0.72-1.6 times length of m-cu; bm-cu parallel to r-m (Fig. 12A). Laterotergite with 0-10 setae. Fore basitarsus 1.75-2 times length of fore tibia. Larvae with rows of 9 and 10 maxillary teeth plus lobe (Fig. 16A).

Redescription. *Adult.* ♂ holotype length 11.2 mm (range 10-13.5 mm (cave), 8-10.5 mm (epigean)). Wing length ♂ 6.5 mm (5.5-8 mm (cave ♂♂), 5-6mm (epigean ♂♂), 6-9 mm (cave ♀♀), 5 mm (epigean ♀♀)). Antennal length 5mm (♂♂), 3mm (♀♀). *Head:* Antennae brown, bases of first few flagellar segments lighter. Scape and pedicel brown. Flagellum with dense mat of brown hairs, except basal quarter of first segment. Diameter of scape 2.4 times diameter of basal flagellar segment (♂♂ 2.3-2.9x, ♀♀ 2.6-3x). First flagellar segment 1.2 times length of second flagellar segment (♂♂ 1.1-1.5x, ♀♀ 1.3-1.6x). Palpi yellow/brown; apical segment lengthened and slightly dilated (also darker); light covering of dark setae on palps. Proboscis yellow/brown (♀♀) to pale yellow (♂♂). *Thorax:* Cluster of long, dark setae on supra-alar region. Shorter, finer setae on post alar area. Laterotergite with 0/2 small setae (TAS2 1-10 setae, TAS5 1-4, TAS6 0-3); sometimes with unequal numbers of setae on each side. Scutum with medium to dark brown shading. Pleura entirely dark brown (encompassing laterotergite, anepimeron, anepisternum, katepsisternum) (Fig. 17A). *Legs:* Coxae white to pale yellow, darkening to dark brown at apices, more extensively so on hind coxa (Fig. 17A). Long dark hairs covering about one third of each coxa, predominantly at apices and on ventral surfaces. Mid basitarsus 1.1 times length of mid tibia; hind basitarsus 0.71 times length of hind tibia (♀♀ 0.77x). *Wings:* Entire wing shaded except for fainter patch basally. Campaniform sensilla located on ♂ wings as follows: 3 on R_1, 4 on Rs, and 1 on proximal end of R_5 (Fig. 12A). TAS2 ♂♂ (R1: Rs: R5) 2-3: 4-6: 1-3, ♀♀ 2-3: 4-6: 2-4, TAS5 ♂♂ 1-2: 2-4: 2-3, ♀♀ 2: 2: 2, TAS6 ♂♂ 1-4: 4-6: 1-2, ♀ 3/7: 5-6: 1-3). Halteres pale yellow/white basally, brown apically with fine hairs. *Abdomen*: External genitalia light brown. *Eggs.* Slightly ovoid. 0.55 x 0.5 mm, red/brown. *Larva.* Larval body colouration with sclerotised brown head capsule (TAS6-cave), body with faint brown/red pigmentation beginning at anterior end, extending down 75% of lateral edges of body (Fig. 15C) (range TAS2-cave: pigmentation green, extending down 60% of lateral edges (Fig.15B); TAS5-epigean: brown/black pigmentation extending entire length of lateral edges (Fig. 15A). Larve up to 4 cm long in fifth instar. Snares ~ 30 cm long in caves, <3 cm in epigean settings. *Pupa.* Suspended from distal tip of abdomen and anterior part of abdomen.

Distribution. *Arachnocampa tasmaniensis* colonies are relatively widespread throughout Tasmania (Goede 1967; Eberhard 1999, 2000). Larvae are primarily found in large numbers in limestone caves. Populations are also widespread in rainforest and along creek banks and walking trail cuttings (Baker 2004; Baker et al. 2008).

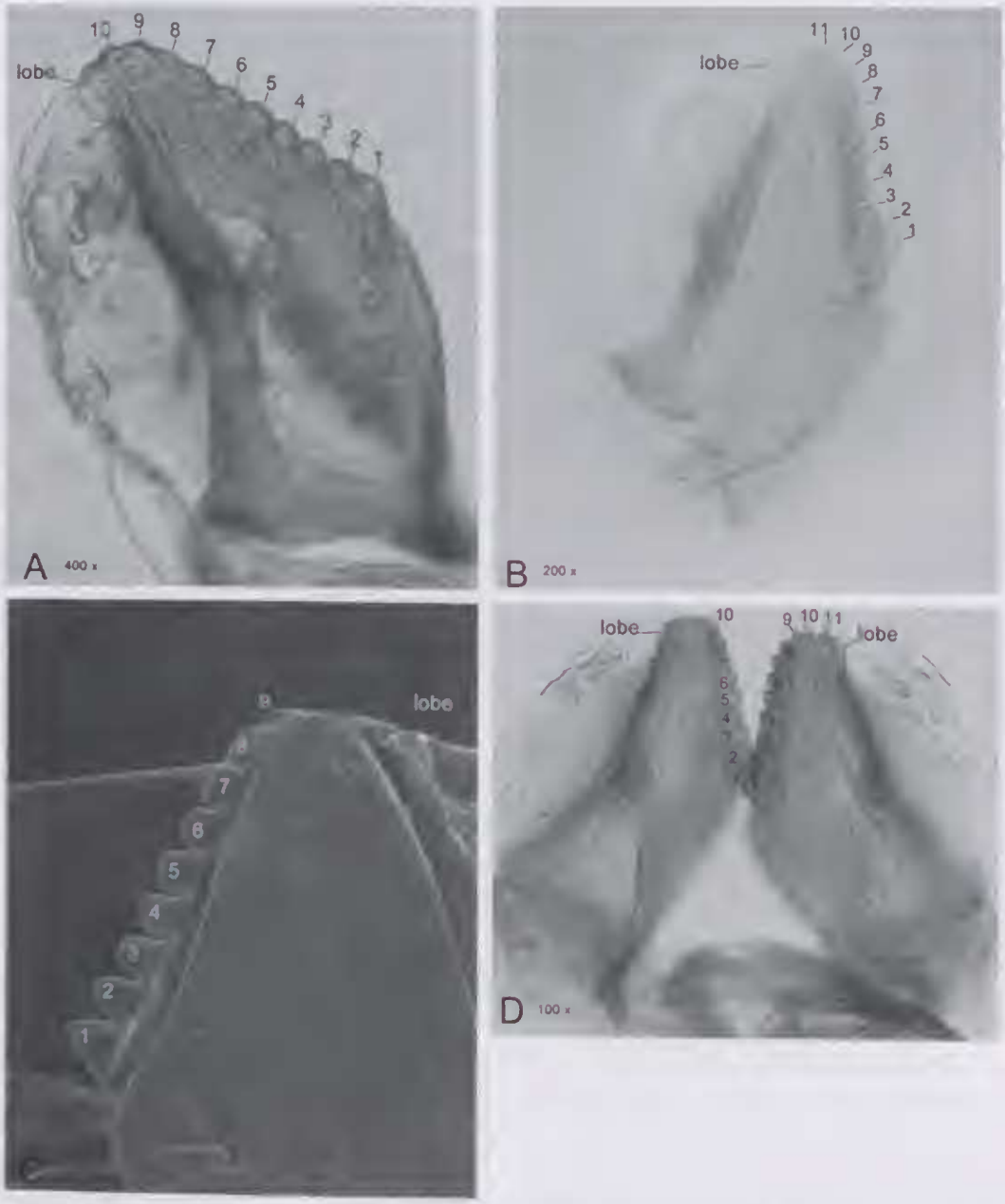

FIG. 16. *Arachnocampa* spp. maxillary teeth. A. *A. gippslandensis* (10 maxillary teeth plus lobe); B, *A. tropica* (10 and 11 maxillary teeth plus lobe); C, *A. flava* (9 and 10 teeth plus lobe (numbers 1-9! + lobe); D, *A. girraweenensis* (10 and 11 maxillary teeth). In most species the number of teeth on one maxilla is different to that on the other.

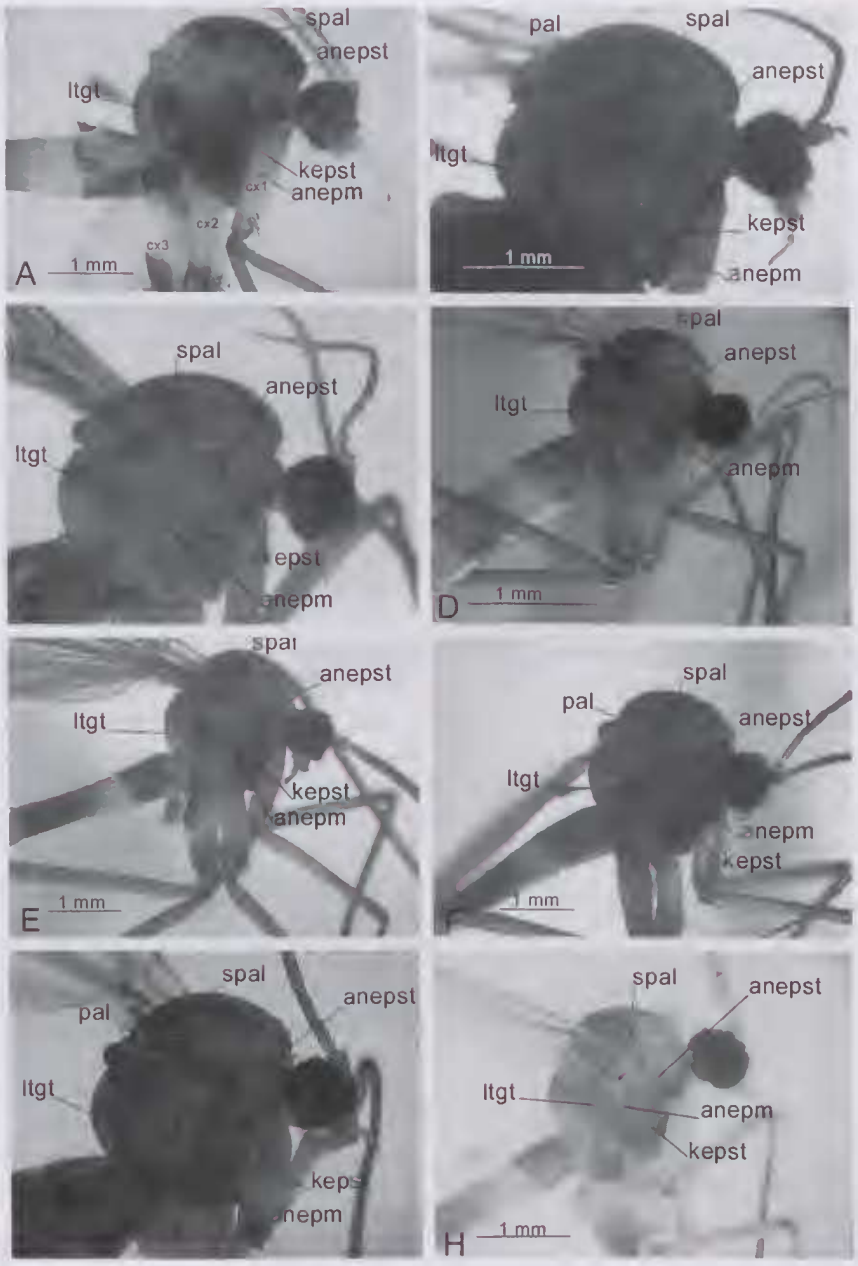

FIG. 17. *Arachnocampa* spp. thoracic segments. A, *A. tasmaniensis*; B, *A. buffaloensis*; C, *A. tropica*; D, *A. flava*; E, *A. girraweenensis*; F, *A. richardsae*; G, *A. gippslandensis*; H, *A. otwayensis*. anepm, anepimeron; anepst, anepisternum; kepst; ltgt, laterotergite; pal, post alar region; spal, supra-alar region.

Comments. Tasmanian populations from which adults were successfully reared for morphological examination were collected from four distinct areas and habitats. Three populations were sampled from limestone caves in both northern (TAS2, 3) and southern (TAS6) areas of the island, and one population was sampled from rainforest in the south (TAS5). Other populations identified during surveys did not produce adults for morphological examination (TAS4), or larvae were not collected from the site for identification (TAS1).

Obvious morphological variation was evident between cave and rainforest (epigean) populations (e.g. in larval colouration, adult body and wing lengths), suggesting that environmental differences experienced by cave and rainforest-dwelling populations have led to phenotypic changes within this species. The close proximity of caves to rainforest populations enables genetic exchange between these habitat types (Baker 2004, Baker et al. 2008). Some morphological variation is evident between northern and southern cave populations. For example, the number of setae on the laterotergite varies from 0-3 for southern cave populations, and 1-10 for northern cave populations. However, this may be due to differing degrees of rainforest population migration into caves or general plasticity within this taxon rather than evidence of speciation. Morphological characters used in this study support Ferguson's (1925) description of this species and its placement within the new subgenus *Lucifera*.

Arachnocampa (*Lucifera*) *buffaloensis* sp. nov.

Arachnocampa buffaloensis Baker et al. 2008 (unavailable name).

Material. HOLOTYPE ♀, Australia, Victoria, Mount Buffalo National Park, Underground River cave, glow-worm grotto, 36°43'S, 151°17'E, 13.iii.2000, CB, collected as adult, killed and stored in 70% ethanol, BUFF#2 (deposited in MV). PARATYPES. VICTORIA, 4 adult ♀♀, Mount Buffalo National Park, Underground River cave, glow-worm grotto, 36°43'S, 151°17'E, 13.i.2001, CB/JF, collected as larva, reared to adult in incubator by CB, BUFF#1,3,4,5. (paratypes deposited in MV and QM)

The following description and measurements are based primarily on the holotype, with other specimens measured for ranges and variation. No males were reared from larvae of this colony.

Diagnosis. Adult body length 10-12 mm. Wing length 6.5-7 mm. m-cu close to r-m (Fig. 12B); bm-cu running parallel to r-m and 1-1.6 times length of m-cu (Fig. 12B). Fore basitarsus 1.55 times length of fore tibia. Laterotergite bare (1 seta on some paratypes). Larvae with row of 10 maxillary teeth plus lobe (Fig. 16A). Larval body colouration: head capsule sclerotised brown, body red, green, blue and white in order from anterior to posterior end. Pigmentation limited to anterior end (Fig. 15D).

Description. *Adults* (♀♀). Body length 11 mm; wing length 7 mm; antennal length 2.8 mm.

Head. Antenna light brown, scape and pedicel light brown, flagellum with dense mat of brown hairs except basal sixth of first flagellar segment. Diameter of scape 2.5 times diameter of basal flagellar segment (range 2.3-2.5x). First flagellar segment 1.4 times length of second segment (1.3-1.45x). Front brown, ridge at dorsal corner of eye ending before centre of front. Longitudinal, deep sulcus above base of antennae. Palpi pale yellow. Apical segment lengthened and slightly dilated (also slightly darker). Proboscis pale yellow. *Thorax:* Large cluster of long, dark setae on supra-alar region, smaller much shorter hairs on post alar area (Fig. 17B). Thoracic dorsum with medium brown shading. Pleura darker brown, lighter in crevice between laterotergite and anepimeron (Fig. 17B). *Legs*: Coxae white to pale yellow. Faint traces of darkening at apices, more extensively so on hind coxa. Dark hairs covering about one third of each coxa. Mid basitarsus equal to length of mid tibia; hind basitarsus

0.81 times length of hind tibia. *Wing*: Shading covering entire wing. m-cu basal to r-m, but closely approximated; r-m sloped forwards towards apex of wing (Fig. 12B); bm-cu 1-1.6 times length of m-cu; m-cu sloping forwards towards apex of wing. Halteres pale yellow basally, brown apically. Campaniform sensillae located on R veins as follows: 1 on R_1, 6 on Rs, and 2 on R_5 (1-3: 6-7: 1-3) (Fig. 12B). *Abdomen*: External ♀ genitalia light brown. All abdominal segments dark brown (paratypes: light-medium brown; darker at distal end of each abdominal segment). *Eggs*. Not seen. *Larva*. Up to 4 cm in length. Larval snares up to 40 cm in length. *Pupa*. Suspended from apex of abdomen and anterior part of abdomen. Bracing thread from thorax to main anterior abdominal suspension thread. Head area black, thorax red/brown, abdomen pale yellow (other Mt Buffalo pupae suspended as for *A. flava*).

Etymology. The specific name refers to the type locality, a single cave in Mt Buffalo National Park, Victoria.

Distribution. At present this species is known only from the Underground River Cave (granite boulder infill cave, 300 m in length with constant water flow) in Mt Buffalo National Park, Victoria. Other caves on private land within the region have been reported to contain glow-worms. However, as yet entry to these other sites has not been granted to the author.

Comments. Data from molecular and morphological studies support *A. buffaloensis* as a sister species to the geographically isolated Tasmanian species *A. tasmaniensis* (Baker 2004; Baker et al. 2008). Theories explaining the current geographic isolation of these sister species are presented in Baker et al. (2008). The cave in which *A. buffaloensis* is found is sub-alpine, where snowfall and subsequent spring melt flooding are an annual event. The extreme seasonal variations and low humidity outside the cave habitat greatly decrease the chances of survival for colonies not within the safety of the cave environment. This species was nominated by the author and has since been listed as *threatened* under the Victorian Government's Flora and Fauna Guarantee Act 1988 on the basis of its extremely restricted habitat of one cave.

Arachnocampa (*Caupara*) *tropica* sp. nov.

Arachnocampa tropica Baker et al. 2008 (unavailable name)
Arachnocampa tropicus Baker et al. 2008 (unavailable name)

Material. HOLOTYPE ♂, Australia, north Queensland, Mt Lewis Rd, Rainforest road cuttings near stream, 16°34.9'S, 145°17'E, 10.vii.2000, CB/AM, collected as larva, reared to adult in incubator by CB, NQLD2#2 (deposited in QM T152171). PARATYPES. QUEENSLAND, ♂, same data as holotype. NQLD2#6; 2♀♀, same data as holotype NQLD2#1, 5; 2♂♂, 5♀♀, Daintree National Park, Mossman Gorge section, council road off Mossman Gorge carpark, road cuttings, 16°25'S, 145°20'E, 14.vii.2000, CB/AM, collected as larvae, reared to adults in incubator by CB, NQLD1#1-6, 8; 1♀, Paluma National Park, Birthday Creek Falls, road cuttings near car park, 18°59'S, 146°10'E, 8.vii.2000, CB/AM, collected as larva, reared to adult in incubator by CB, NQLD9#1; 1♂, Wooroonoran National Park: Josephine Falls section, Bartle Frere trail, western approach, Bobbin Bobbin Falls, stream banks, 17°22'S, 145°47'E, 9.vii.2000, CB/AM, collected as larva, reared to adult in incubator by CB, NQLD6#1; 1♀, Wooroonoran National Park: Josephine Falls section, Bartle Frere trail, western approach, granite boulder cave off trail near summit, 17°22'S, 145°49'E, 9.vii.2000, CB/AM, collected as larva, reared to adult in incubator by CB, NQLD5#3; 5♂♂, 1♀, Mt Hypipamee National Park, Dinner Falls walking trail banks near stream, 17°26'S, 145°28'E, 9.vii.2000, CB/AM, collected as larva, reared to adult in incubator by CB, NQLD4#1-6; 1♀, Mt Hypipamee National Park, Dinner Falls walking trail banks near stream, 17°26'S, 145°28'E, 11.vi.2002, CB/AM, collected as larva, reared to adult in incubator by CB, NQLD4Ri#1; 2♂♂, 2♀♀, Tully Falls State Park, Charmillan walking trail banks near stream, 17°43'S, 145°31'E, 9.vii.2000, CB/AM, collected as larva, reared to adult in incubator by CB, NQLD8#1-4. (paratypes deposited in AM, MV, QM, TM and UQIC).

The following description and measurements are based primarily on the holotype, with other specimens measured for ranges and variation.

Diagnosis. Adult body length 7-8 mm (♂♂), 7-9 mm (♀♀). Wing length 5-6 mm (♂♂), 5.5-6.5 mm (♀♀). Antennal length 3-3.5 mm (♂♂), 2mm (♀♀). bm-cu curved backwards and 1.7-2.5 x length of m-cu. m-cu sloping forwards (Fig. 12C). Laterotergite with 2-12 (♂♂), 3-30 (♀♀) setae. Larvae with 10 and 11 maxillary teeth (Fig. 16B). Larval head capsule sclerotised brown, body with faint brown/red pigmentation beginning at anterior end, extending down entire length of lateral edges of body. Malpighian tubules black (Fig. 15E).

Description. *Adult.* ♂ holotype body length 8 mm; wing length 5 mm; antennal length 3.2 mm.

Head. Antennae yellow to brown, lighter at basal end of first flagellar segment; scape and pedicel yellow. Flagellum with dense mat of brown hairs, except basal quarter of first flagellar segment. Diameter of scape 2.25 times diameter of basal flagellar segment in holotype ♂ (♂♂ 2.25-2.7x, ♀♀ 2.6-3.4x). First flagellar segment 0.88 times length of second flagellar segment (♂♂ 0.88-1.4x, ♀♀ 0.93-1.2x). Front medium to dark brown. Dark setae on head. Face medium brown to dark brown with thick cluster of setae over facial carina. Palpi pale yellow; apical segment lengthened and slightly dilated; light covering of dark setae on palps. Proboscis pale yellow to brown. *Thorax*: Cluster of long, dark setae on supra-alar region and on post alar area (Fig. 17C). Laterotergite with 6 small setae (♂♂ 2-12, ♀♀ 2-30); sometimes with unequal numbers of setae on each side. All thoracic dorsum with medium brown shading. Pleura (encompassing laterotergite, anepisternum, anepimeron and katepisternum) slightly darker medium brown and more heavily shaded in centre of sclerites (Fig. 17C). *Legs:* Coxae pale yellow, darkening to medium/dark brown at apices, more extensively so on hind coxa. Long, dark hairs covering about one quarter of each coxa, predominantly at apices and ventral surfaces. Other segments of legs yellow/brown. Fore basitarsus 1.5 times length of fore tibia (1.2-1.5x); Mid basitarsus equal to length of mid tibia (♀♀ 0.83x); hind basitarsus 0.83 times length of hind tibia (♀♀ 0.66-0.83x). *Wings*: Shading covering entire wing except for a fainter patch at wing base. Halteres pale yellow basally, brown apically with fine hairs. Campaniform sensilla located on ♂♂ wings as follows: 2 on R_1, 4 on Rs, and 3 on R_5 (Fig. 12C) (♂♂ range 1-3: 3-6: 1-3, ♀♀ 1-3: 3-5: 1-4). *Abdomen*: External genitalia medium brown. *Eggs*. 0.48 x 0.43 mm, yellow/brown with slightly red tinge (virgin ♀♀ eggs). *Larva*. Intestines green. Larval snares <3 cm. *Pupa*. Suspended from apex of abdomen and anterior part of abdomen.

Etymology. The specific name tropica refers to the type locality's distribution within the world heritage-listed Wet Tropics region of north Queensland, Australia.

Distribution. This species has been recorded in rainforest and small granite boulder caves throughout the Wet Tropics rainforests of far north Queensland. It is likely that this species is more widespread in the rainforests of this region, however a detailed survey is yet to be conducted. Populations have been observed to expand rapidly during the northern wet season (November – March), only to drop back in numbers through the remainder of the year due to drier conditions (personal observations).

Comments. Morphological and molecular data distinguish *A. tropica* from all other species in the genus. A large geographic distance separates this northern clade from other Australian populations of *Arachnocampa*. Genetic data suggest two species may be present in far north Queensland following two phases of expansion into the tropics (Baker 2004, Baker et al. 2008). Verification of this distinction requires genetic analysis at the population level. Individual

colonies of this species were usually low in numbers of individuals and density, with no spectacular displays noted. Larvae collected from the Wet Tropics were heavily parasitised by an undescribed species of ichneumonid wasp (Baker 2004; Chris Burwell, pers. comm.). This wasp has not been recorded from colonies further south but could represent a significant threat to the tourism industry associated with glow-worms in southeast Queensland if it dispersed or was translocated to the region.

Arachnocampa (*Campara*) *flava* Harrison, 1966

Arachnocampa flava Harrison 1966: 882.

Material Examined. HOLOTYPE ♂ (QM Reg. No. T6430) Queensland, Numinbah 21.iv.1935 F.A. Perkins (QM). OTHER MATERIAL. NEW SOUTH WALES, 3♂♂, 4♀♀, Mt Warning National Park, Korrumbyn picnic area, vertical creek banks, 28°24'S, 153°16'E, 27.iii.2000, CB/JF, collected as larvae, reared to adults in incubator by CB, CALD5#1-7; 2♀♀, Mt Warning National Park, Korrumbyn picnic area, vertical creek banks, 28°24'S, 153°16'E, 5.vii.2002, AR/CB, collected as larvae, reared to adults in incubator by CB, CALD5#Ri1-2; 4♂♂, 4♀♀, Nightcap National Park, Protesters Falls walk, vertical creek banks, 28°34'S, 153°17'E, 27.iii.2000, CB/JF, collected as larvae, reared to adults in incubator by CB, CALD6#1-8. QUEENSLAND: 6♂♂, 10♀♀, Springbrook-Mudgeeraba Road, Springbrook Gully, vertical creek banks, 28°12.5'S, 153°17.5'E, 23.v.2001, CB, collected as larvae, reared to adults in incubator by CB, CALD3#4, 12, 14-17, 21, 23, 31, 33, 34, 39, 41-43, Rix.

Diagnosis. Adult body length 6.5-8.5 mm (♂♂), 7-10 mm (♀♀); wing length 4.5-5 mm (♂♂), 4.6-6.5 mm (♀♀); antennal length 3.5-4 mm (♂♂), 2 mm (♀♀). bm-cu curved backwards and 1.9-2.7 times length of m-cu (Fig. 12D). Laterotergite with 0-7 setae. Larval colouration: head capsule sclerotised brown, body with dark brown/red pigmentation extending along entire lateral edges of body (Fig. 15F). Intestines green. Malpighian tubules black. Larval maxillae with rows of 9 and 10 teeth (Fig. 16C).

Description. *Adult.* ♂ holotype body length 8 mm; wing length 5mm; antennal length 4 mm.

Head. Antennae light to medium brown, light yellow at basal end of first few flagellar segments. Scape and pedicel pale yellow. Flagellum with dense mat of brown hairs, except basal fifth of first segment. Diameter of scape 2.7 times diameter of basal flagellar segment in holotype ♂ (♂♂ 2.6-3.1x) and 3-3.6 times length of second flagellar segment in ♀♀. Scape with very sparse setae around ventral apex. First flagellar segment 1.3 times length of second flagellar segment (♂♂ and ♀♀ 1.1-1.3x). Front medium to dark brown. Strong dark setae covering ridge. Face medium brown with thick cluster of setae over facial carina. Palpi pale yellow; apical segment lengthened and slightly dilated; light covering of dark setae on palps. Proboscis yellow/brown (♀♀) to pale yellow (♂♂). *Thorax*: Cluster of long, dark setae on supra-alar region. Shorter, finer setae on post alar area. Laterotergite with 2/1 small setae (0-7); sometimes with unequal numbers of setae on each side. Scutum with medium yellow/brown shading. Pleura (encompassing laterotergite, anepisternum, anepimeron and katepisternum) medium to dark brown, crevices between sclerites slightly lighter. *Legs:* Coxae white to pale yellow, darkening to dark brown at apices, more extensively so on hind coxa. Dark hairs covering about one quarter of each coxa, predominantly at apices and on ventral surfaces. Other segments of legs yellow to brown. Fore basitarsus 1.5 times length of fore tibia (♀♀ 1.1x); mid basitarsus 1.1 times length of mid tibia (♀♀ 0.77x); hind basitarsus 0.71 times length of hind tibia (♀♀ 0.77x). *Wings*: Shading covering entire wing with only a fainter basal patch. Halteres pale yellow basally, brown apically with fine hairs. Campaniform sensillae located on ♀♀ wings as follows: 2 on R_1, 2-4 on Rs, and 1-3 on R_5 (beyond r-m) (♀♀ 1-3: 2-5: 1-3). *Abdomen*: External genitalia yellow/brown. *Eggs*. 0.42 x 0.36 mm, orange/cream coloured

when deposited; darkening over time to dark red/brown. *Larva*. 3-4 cm in length in 5th instar. Larval snares <5 cm. *Pupa*. Suspended from apex of abdomen and anterior part of abdomen. Abdomen orange.

Distribution. Populations are found in rainforest gullies and along rainforest stream banks throughout the Mt Warning caldera. Colonies reach their highest numbers in one congregation at a large overhang, Natural Bridge, Springbrook National Park. Other notable colonies are in the Sprinbrook Plateau, the Border Ranges, Main Range and Tamborine Mountain (David Newell, herpetologist, Southern Cross University, Conrad Hoskin, herpetologist, Australian National University, pers. comm.). These additional populations were not surveyed for this study.

Comments. Elevated numbers of *A. flava* within rainforest colonies occur during periods of warm, wet weather (Baker 2002). The distribution of *A. flava* now includes colonies from Mt Warning (CALD5) and Nightcap National Park (CALD6). Colonies at Tamborine Mountain (TAM1), O'Reilly's, Lamington National Park (CALD4), and Kroombit Tops (samples sent from Harry Hines, Queensland National Parks) are tentatively placed in this species based on molecular evidence from two mitochondrial genes (Baker et al. 2008). The author would like to conduct a morphological examination of adults from the Kroombit Tops population to ascertain their correct placement, as a large barrier of unsuitable habitat exists between these populations. However as yet, only preserved larvae have been obtained.

Arachnocampa (*Campara*) *girraweenensis* sp. nov.

Arachnocampa girraweenensis Baker et al. 2008 (unavailable name).

Material. HOLOTYPE ♂, Australia, Queensland, Girraween National Park, South Bald Rock cave, 28°54'S, 152°01'E, 24.iii.2001, ASH/CB/DM, collected as larva, reared to adult in incubator by CB, GIRRA2#12 (deposited in QM T152149). PARATYPES. QUEENSLAND, ♀, Girraween National Park, South Bald Rock cave, 28°54'S, 152°01'E, 6.vii.2002, AR/CB, collected as larva, reared to adult in incubator by CB, GIRRA2Ri#A; 2♂♂, 5♀♀, Girraween National Park, South Bald Rock cave, 28°54'S, 152°01'E, 24.iii.2001, ASH/CB/DM, collected as larvae, reared to adults in incubator by CB, GIRRA2#1, 4-6, 8 10-11; 2♂♂, 1♀, Girraween National Park, Ramsey Creek, Underground River cave, 28°51'38.9'S, 151°55'47.3E, 6.vii.2002, AR/CB, collected as larvae, reared to adults in incubator by CB, GIRRA1Ri#1-3; 1♂, 3♀♀, Girraween National Park, Ramsey Creek, Underground River cave, 28°51'38.9'S, 151°55'47.3E, 23.iii.2001, ASH/CB/DM, collected as larvae, reared to adults in incubator by CB, GIRRA1Ri#4,8,9,11. NEW SOUTH WALES, 1♀, Bellingen Shire, Cleaver's Bridge, 30°27'S, 152°54'E, 25.iii.2000, CB/JF, collected as larva, reared to adult in incubator by CB, NNSW2#1; 3♂♂, 1♀, Barrington Tops National Park, Gloucester Tops, Sharpe's Creek Walk, trail banks near creek, 32°03'S, 151°40'E, 24.iii.2000, CB/JF, collected as larva, reared to adult in incubator by CB, NNSW4#1, 3-5; 3♂♂, 2♀♀, Washpool National Park, Washpool walk, trail banks near stream, 29°16'S, 152°22'E, 26.iii.2000, CB/JF, collected as larvae, reared to adults in incubator by CB, NNSW1#1-5. (paratypes deposited in AM, MV, QM, TM and UQIC).

The following description and measurements are based primarily on the holotype, with ranges taken from other specimens.

Diagnosis. Adult body length 8.5-11 mm (cave ♂♂), 7-8.5 mm (epigean ♂♂), 8-11 mm (cave ♀♀), 7-9 mm (epigean ♀♀); wing length 5-6.2 mm (cave ♂♂), 6-7.2 mm (cave ♀♀), 5-6 mm (epigean ♂♂ and ♀♀); antennae 4-5 mm (cave ♂♂), 2-3 mm (cave ♀♀), 3-3.5 mm (epigean ♂♂), 2 mm (epigean ♀♀). Laterotergite with 0-5 setae. bm-cu curved and angled backwards, 2-4.5 times length of m-cu (cave) (1.8-3.2x epigean) (Fig. 12E). Larvae with 10 and 11 maxillary teeth (Fig. 16D). Larval head capsule sclerotised brown, body with brown/red pigmentation beginning at anterior end, extending down 30% of lateral edges of body (Fig. 15G, H). Malpighian tubules white to pale brown. Larval snares <5 cm.

Description. *Adult.* ♂ holotype (cave) body length 11 mm; wing length cave 6.2 mm; antennal length 5 mm. *Head*: Antennae medium brown, light yellow at bases of first few flagellar segments. Scape and pedicel pale yellow. Flagellum with dense mat of brown hairs, except basal sixth of first segment. Diameter of scape 2.6 (cave ♂♂ range 2.3-2.6, epigean ♂♂ 2.2-2.8) times diameter of basal flagellar segment, in ♂♂ and 2.4-3.3 times length of second flagellar segment in cave ♀♀ (epigean ♀♀ 3-3.7x). First flagellar segment 1.4 times length of second flagellar segment (range 1.1-1.4x). Front dark brown. Face medium to dark brown with thick cluster of setae over facial carina. Palpi yellow/brown; apical segment lengthened and slightly dilated (also darker); light covering of dark setae on palps. Proboscis yellow. *Thorax*: Cluster of long, dark setae on supra-alar region. Shorter, finer setae on post alar area. Laterotergite with 3/3 dark setae (range cave ♂♂ 3, epigean ♂♂ 0-3, cave ♀♀ 1-5, epigean ♀♀ 0-4); sometimes with unequal numbers of setae on each side. Row of small setae along lateral margins of scutum. Scutum with medium brown shading. Pleura light to medium brown (encompassing laterotergite, anepisternum, anepimeron and katepisternum); anepimeron lighter (Fig. 17E). *Legs:* Coxae pale yellow, darkening to light to medium brown at apices, more extensively so on hind coxa. Long dark hairs covering about one third of each coxa, predominantly at apices and ventral surfaces. Fore basitarsus 1.4 times length of fore tibia (♀♀ 1.4x); mid tarsus 1.1 times length of mid tibia (♀♀ 0.83x); hind basitarsus 0.71 times length of hind tibia (♀♀ 0.65x). *Wings*: Halteres pale yellow/white basally, yellow/brown apically with fine hairs. Campaniform sensillae located on ♂ wings as follows: 3 on R_1, 4 on Rs, and 3 on R_5 (Fig. 12E) (♂♂ cave range 2-4: 3-4: 2-3, ♂♂ epigean 2-3: 2-3: 1-3). *Abdomen*: External genitalia medium brown. *Eggs*. Slightly ovoid. 0.56 mm x 0.48 mm, yellow/brown (virgin ♀♀ eggs). Larval snares <4 cm. *Pupa*. Suspended from apex of abdomen and anterior part of abdomen. Abdomen yellow/brown with eggs clearly visible.

Etymology. The specific name refers to the type locality of Girraween National Park, Queensland, in which the two isolated cave populations are located.

Distribution. This species is restricted to two continuously wet granite boulder caves in Girraween National Park, Queensland, extending into nearby rainforest within and around Washpool National Park (NNSW1), New England National Park (NNSW2), Dorrigo National Park (NNSW3), Barrington Tops National Park (NNSW4) and one small cave in Gloucester, New South Wales.

Comments. Morphological differences are evident between the cave and rainforest (epigean) colonies described here (including body size, colour and the number of setae on the laterotergite). However, these differences are likely to result from the environmental conditions in the habitat in which they live rather than reflect species differences. Larval snares are short despite being in a cave environment. Molecular data support *A. girraweenensis* as the sister species to *A. flava*, and link the cave populations of *A. girraweenensis* in Queensland to those in nearby rainforest, now separated by unsuitable habitat (Baker et al. 2008).

Arachnocampa (*Campara*) *richardsae* Harrison, 1966

Arachnocampa richardsae Harrison, 1966: 881.

Material Examined. HOLOTYPE ♂ bearing the label: Australia, Newnes Railway Tunnel, New South Wales. Collected as pupa 15.x.1961, adult 20.x.1961, coll. A.M. Richards (ANIC).

Other Material. NEW SOUTH WALES, 3♂♂, 4♀♀, Wollemi National Park, Newnes Railway Tunnel, 33°11'S, 150°14'E, 14.vii.2000, CB/JF, collected as larva (1♂ and 1♀ collected as adults), reared to adult in incubator by CB, SNSW1#1-4, 6-8; 2♀♀, Wollemi National Park, Newnes Railway Tunnel, 33°11'S, 150°14'E, 28.vi.2002, CB/AR, collected as larvae,

reared to adults in incubator by CB, SNSW1Ri#1, 4; 3♂♂, Blue Mountains National Park, Grand Canyon Walk, rainforest canyon near stream, 33° 39'S, 150°19'E, 23.iii.2000, CB/JF, collected as larvae, reared to adults in incubator by CB, SNSW4#1-3; 1♀, Blue Mountains National Park, Grand Canyon Walk, rainforest canyon near stream, 33°39'S, 150°19'E, 28.vi.2002, CB/AR, collected as larva, reared to adult in incubator by CB, SNSW4Ri#4; 2♂♂, 4♀♀, Morton National Park, Glow-worm Grotto, overhang over waterfall in rainforest, 34°39'S, 150°29'E, 23.iii.2000, CB/JF, collected as larvae, reared to adults in incubator by CB, SNSW6#1-6.

The following redescription and measurements are based primarily on a male, SNSW1#1, from Wollemi National Park, Newnes Railway Tunnel, with other specimens measured for ranges and variation.

Diagnosis. Body length 10-11 mm (♂♂ cave), 7-7.5 mm (♂♂ epigean), 9-11.5 mm (♀♀ cave), 9 mm (♀♀ epigean); wing length 6.5-7.5 mm (♂♂ cave), 5.2-6 mm (epigean ♂♂), 6-8.5 mm (♀♀ cave), 5-6 mm (♀♀ epigean); ♀♀ cave antennae 3 mm, epigean ♀♀ 2-2.2 mm. m-cu well distal to r-m. r-m cross vein straight. bm-cu curved and 1.5-3 times (SNSW1 1.8-2.8x, SNSW6 2.3x, SNSW4 1.5-3x) length of m-cu, sloping backwards, towards wing base (Fig. 12F). m-cu sloping forwards. Laterotergite with 0-21 setae. Larval malpighian tubules light to medium brown (Fig. 15I, J). Larval maxillary teeth 9 and 10 plus lobe (cf Fig. 16A, C). Larval colouration: head capsule sclerotised brown, body with green pigmentation extending along entire length of lateral edges of body. Some brown/red pigmentation at posterior end (Fig. 15I, J).

Redescription. *Adults.* ♂ holotype body length 11 mm; wing length 7.5 mm; antennal length 5 mm. *Head*: Antennae brown, lighter at bases of first few flagellar segments. Scape and pedicel yellow to light brown. Flagellum with dense mat of brown hairs, except basal sixth of first segment. Diameter of scape 2.4 times diameter of basal flagellar segment in ♂ (2.2-3.4x). First flagellar segment 1.04 times length of second flagellar segment (1.04-1.4x). Front dark brown. Dark setae behind ridge. Face medium to dark brown with cluster of setae over facial carina. Palpi yellow to light brown; apical segment lengthened and slightly dilated; light covering of dark setae on palps. Proboscis yellow/brown (♀♀) to pale yellow (♂♂). *Thorax*: Cluster of very long, dark setae on supra-alar region and post alar area (Fig. 17F). Laterotergite with 20/21 small setae on ♂ (♂♂ 6-21, 8-17 on ♀♀) (SNSW4 ♂♂ 1-7, SNSW4/SNSW6 ♀♀ 0-3); sometimes with unequal numbers of setae on each side. Scutum with medium brown shading. Pleura medium brown (encompassing laterotergite, anepisternum, anepimeron and katepisternum). *Legs*: Coxae pale yellow, darkening to medium brown at apices, slightly more extensively so on hind coxa. Very long dark hairs covering about one third of each coxa, predominantly at apices and ventral surfaces. Fore basitarsus 1.3 times length of fore tibia (♀♀ 1.2x); Mid basitarsus 1.1 times length of mid tibia; hind basitarsus 0.66 times length of hind tibia (♀♀ 0.65x). *Wings*: Shading covering entire wing, only with a fainter patch at base. Halteres pale yellow basally (♀♀), white (♂♂), brown apically with fine hairs. Campaniform sensillae located on ♂ wing as follows: 4 on R_1, 4 on Rs, and 4 on R_5 (Fig. 12F) (SNSW1 ♂♂ 3-4: 3-5: 4-6, SNSW1 ♀♀ 3-4: 4-5: 4/7, SNSW4 ♂♂ 2-3: 2-4: 3-5, SNSW6 ♀♀ 2:3:2, ♂♂ 2: 3-4: 2). *Abdomen*: External genitalia medium to dark brown. *Eggs*. 0.55 x 0.48 mm, cream brown - red/brown (virgin ♀♀ eggs). *Larva*. 5th instar 3-4 cm in length. Larval snares <5cm. *Pupa*. Suspended from apex of abdomen and anterior part of abdomen.

Distribution. This species is found in fragmented rainforest areas from Gosford (SNSW2), the Blue Mountains (SNSW1, 3, 4) to Bundanoon (SNSW5) and Fitzroy Falls (SNSW6), New South Wales.

Comments. Initially described by Harrison (1966), the largest known colony is found in the man-

made Newnes railway tunnel. This is probably due to the water seepage within the tunnel, the abundance of prey items and protection from fire. Morphologically, cave and epigean populations exhibit differences in body size and colouration. Again these differences are likely to be due to morphological plasticity rather than reflect species differences. Harrison's use of colour for distinguishing *A. flava* from *A. richardsae* can be problematic given the large colour variation within these species. The darkened malpighian tubules in the larvae of *A. flava* is a more reliable character to separate the species.

Arachnocampa (*Campara*) *gippslandensis* sp. nov.

Arachnocampa gippslandensis Baker et al. 2008 (unavailable name).

Material Examined. HOLOTYPE ♂, Australia, Victoria, Yarra Valley, Old Warburton Road, Shining Star mine tunnel, 37°46'S, 145°38'E, 12.i.2001, CB, collected as larva, reared to adult in incubator by CB, EVIC4#3 (deposited in MV). PARATYPES: VICTORIA, 2♂♂, Yarra Valley, Old Warburton Road, Shining Star mine tunnel, 37°46'S, 145°38'E, 16.iii.2000, CB/JF, collected as larva, reared to adult in incubator by CB, EVIC4#1-2; 1♂, Yarra Valley, Old Warburton Road, Shining Star mine tunnel, 37°46'S, 145°38'E, 12.i.2001, CB, collected as larva, reared to adult in incubator by CB, EVIC4#4; 1♂, 1♀, Yarra State Forest, Britannia Creek Rd, Britannia Creek cave, 37°48'S, 145°40'E, 14.vi.2002, CB/AM, collected as larvae, reared to adults in incubator by CB, EVIC3#3-4; 1♀, Yarra Ranges National Park, Peninsula Road, Goldfields Walk, Upper Yarra goldmine tunnel, 37°39'S, 145°53'E, 14.vi.2002, CB/AM, collected as larvae, reared to adults in incubator by CB, EVIC1#2; 3♂♂, 1♀, Walhalla, Long Tunnel Extended, horizontal mine shaft, 37°57'S, 146°27'E, 14.vi.2002, CB/AM, collected as larvae, reared to adults in incubator by CB, EVIC7Ri #1-4. (paratypes deposited in AM, MV, QM, TM and UQIC).

The following description and measurements are based primarily on the holotype, with other specimens measured for ranges and variation.

Diagnosis. Adult body size 10-12 mm (♂♂), 11.5-12.2 mm (♀♀); wing length 6.5-7.5 mm (♂♂), 7-8 mm (♀♀); antennal length 4.5-5 mm (♂♂), 3.2-3.3 mm (♀♀). 0-1 setae on laterotergite. m-cu well distal to r-m. r-m at 90 degrees to R (EVIC3) or anteriorly sloped slightly backwards towards the base of wing (EVIC1, 4, 7) (Fig. 12G). bm-cu 1.75-2.6 times length of m-cu, curved, and angled backwards towards base of wing (EVIC1, 3, 7) (EVIC4 bm-cu 1.3-1.4 times length of m-cu, straight, angled forwards towards apex of wing). Larval maxillae with rows of 9 and 10 teeth (Fig. 16A). Larval colouration: Head capsule sclerotised brown, body with faint brown/red pigmentation beginning at anterior end, extending down 25% of lateral edges of body (Fig. 15K, L). Intestines brown to green. Malpighian tubules white to pale brown (Fig. 15K, L).

Description. *Adult.* ♂ holotype body length 11.5 mm; wing length 7 mm; antennal length 5 mm. *Head*: Antennae brown, lighter at bases of first few flagellar segments. Scape and pedicel light yellow to brown. Flagellum with dense mat of brown hairs, except basal fifth of first segment. Diameter of scape 2.8 times diameter of basal flagellar segment in ♂ (♂♂ 2-2.9x, ♀♀ 2.7-3.1x). First flagellar segment 1.5 times length of second flagellar segment (♂♂ 1.3-1.5x, ♀♀ 1.09-1.4x). Front dark brown. Face medium brown with thick cluster of setae over facial carina. Palpi yellow/brown; apical segment lengthened and slightly dilated (also darker); light covering of dark setae on palps. Proboscis yellow/brown. *Thorax*: Cluster of long, dark setae on supra-alar region (Fig. 17G). Shorter, finer setae on post alar area. Scutum medium brown shading. Pleura sclerotised dark brown (Fig. 17G) (encompassing laterotergite, anepisternum, anepimeron and katepisternum). *Legs:* Coxae yellow, darkening to medium brown at apices, more extensively so on hind coxa. Long dark hairs covering about one third of each coxa, predominantly at apices and on ventral surfaces. Other segments of legs brown. Fore basitarsus 1.4 times length of fore tibia (♂♂ and ♀♀); mid

basitarsus 1.1 times length of mid tibia (♂♂ and ♀♀): hind basitarsus 0.71 times length of hind tibia (♀♀ 0.66x). *Wings*: Halteres pale yellow/white basally, brown apically with fine hairs. m-cu distal to r-m but position variable: EVIC1 with m-cu closer to r-m, EVIC3 and EVIC7 with m-cu closer to M vein split, EVIC4 with m-cu in middle. Campaniform sensillae located on ♂ holotype wing as follows: 4 on R1, 5 on Rs, and 5 on R5 (Fig. 12G) (♂♂ 3-4: 4-5: 3-5, ♀♀ 3-4: 3-5: 4-5). *Abdomen*: External genitalia light brown with black tips. *Eggs*. Slightly ovoid. 0.5 mm x 0.6 mm, brown (virgin ♀♀ eggs). *Larva*. Larval snares <3 cm. *Pupa*. Suspended from apex of abdomen and anterior part of abdomen. Threads turn golden after pupation (although may be an artefact of the environment).

Etymology. The specific name refers to the type locality of Gippsland, Victoria, Australia.

Distribution. *Arachnocampa gippslandensis* colonies are found in rainforest and man-made mine tunnels in the Gippsland region of Victoria.

Comments. There is strong morphological and molecular support for the separation of the eastern Victorian *Arachnocampa* populations as a distinct species (Baker et al. 2008). Specimens from this species were first noted in the literature by Harrison (1966) from samples collected at Walhalla by Elery Hamilton-Smith in 1965. At that time, this population was tentatively grouped with *A. richardsae*, but without morphological examination. Recent fires (February 2009) through this region may have greatly decreased the available habitat of this species and, as such, field surveys are recommended.

Arachnocampa (*Campara*) *otwayensis* sp. nov.

Arachnocampa otwayensis Baker et al., 2008 (unavailable name).

Material Examined. HOLOTYPE ♂, Australia, Victoria, Melba Gully State Park, Madsen Track, stream and trail banks, 38°41.8'S, 143°22.2'E, 10.vi.2002, CB/AM, collected as larva, reared to adult in incubator by CB, WVIC1Ri1 (deposited in MV). PARATYPES. VICTORIA, 1♂, Hopetoun Falls, stream banks, 38°40'S, 143°34'E, 9.iii.2000, CB/JF, collected as larva, reared to adult in incubator by CB, WVIC3#1; 1♂, 1♀, Angahook-Lorne State Park, Kennett River picnic area, stream banks, 38°40'S, 143°49'E, 9.iii.2000, CB/JF, collected as larvae, reared to adults in incubator by CB, WVIC5#2-3; 1♂, 1♀, Angahook-Lorne State Park, Sheoak picnic area, stream banks, 38°33'S, 143°56'E 12.iii.2000, CB/JF, collected as larvae, reared to adults in incubator by CB, WVIC6#1-2; 1♂, Angahook-Lorne State Park, Sheoak picnic area, stream banks, 38°33'S, 143°56'E, 10.vi.2002, CB/AM, collected as larvae, reared to adults in incubator by CB, WVIC6Ri#1; 2♂♂, 1♀, Beauchamp Falls, base of waterfall and surrounding stream banks, collected as larvae, reared to adults in incubator by CB, 38°39'S, 143°37'E, 12.iii.2000, CB/JF, WVIC2#1-3; 1♂, 1♀, Beauchamp Falls, base of waterfall and surrounding stream banks, 38°39'S, 143°37'E, 10.vi.2002, CB/AM, collected as larvae, reared to adults in incubator by CB, WVIC2Ri#1-2. (paratypes deposited in AM, MV, QM, TM and UQIC).

The following description and measurements are based primarily on holotype, with other specimens measured for ranges and variation.

Diagnosis. Adult body size 6.5-8.5 mm (♂♂), 8 mm (♀♀); wing length 4.5-5.5 mm ♂♂, 5-6 mm ♀♀. Antennae 4-5 mm ♂♂, 2-2.2 mm ♀♀. 0-5 setae on laterotergite. m-cu located halfway between r-m and fork of M (well beyond r-m) (Fig. 12H). r-m straight. bm-cu curved, 2.4-3.3 times length of m-cu, sloping slightly backwards, towards base of wing (Fig. 12H). Larvae with 9 and 10 maxillary teeth plus lobe (cf Fig. 16A, C).

Description. *Adult*. ♂ holotype body length 7 mm; wing length 5 mm; antennal length 4.5 mm. *Head*: Antennae brown, pale yellow at basal end of first few flagellar segments. Scape and pedicel yellow. Flagellum with dense mat of brown hairs, except basal seventh of first segment. Diameter of scape 2.6 times (2.6-3.2x) diameter of basal flagellar segment in ♂♂ (♀♀ 2.8-3.6x). First flagellar segment 1.3 times length of second flagellar segment (♂♂ 1.2-1.3x,

♀♀ 1.2-1.4x). Front medium to dark brown. Face medium brown with cluster of setae over facial carina. Palpi very pale yellow; apical segment lengthened and slightly dilated; light covering of dark setae on palps. Proboscis pale yellow. *Thorax*: Cluster of long, dark setae on supra-alar and post alar regions (Fig. 17H). Laterotergite with 0-3 small setae (0-5); sometimes with unequal numbers of setae on each side. Medium brown shading on scutum. Pleura dark brown (encompassing laterotergite, anepisternum, anepimeron and katepisternum). Entire thorax moderately shaded (light to medium brown). *Legs:* Coxae yellow to brown, darkening to dark brown at apices, more extensively so on hind coxa. Long dark hairs covering about one third of each coxa, predominantly at apices and on ventral surfaces. Other segments of legs brown. Fore basitarsus 1.3 times length of fore tibia (♀♀ 1.1x): Mid basitarsus 0.83 times length of mid tibia (♀♀ 0.74x): Hind basitarsus 0.62 times length of hind tibia (♀♀ 0.65x). *Wings*: Halteres pale yellow basally, brown apically with small hairs. Campaniform sensillae located on ♂♂ wings as follows: 2 on R1, 3 on Rs, and 1 on R5 (Fig. 12H) (♂♂ 1-2: 2-4: 1-3, total average = 7, range 6-8), (♀♀ 2-3: 4-5: range 1-3, total average = 9, range 8-10). *Abdomen*: External genitalia medium brown. *Eggs*. Slightly ovoid. 0.48 x 0.45 mm, cream/brown. *Larva*. Larval snares <3 cm. *Pupa*. Suspended from apex of abdomen and anterior part of abdomen.

Etymology. The specific name refers to Otway National Park, Victoria, which contains many colonies of this species.

Distribution. This species is restricted to rainforest gullies and stream banks in Otway National Park, Melba Gully State Park and Angahook-Lorne State Park and adjoining private land containing rainforest, southwest Victoria.

Comments. McKeown (1935) noted the presence of *Arachnocampa* in the Otway Forest, Victoria. This population of *Arachnocampa* species remained undescribed until the current study, although previously it had been tentatively identified as *A. richardsae* (Crosby 1978). Molecular data indicate *A. otwayensis* is the sister species to *A. gippslandensis* + *A. richardsae* (Baker et al. 2008). The colouration of fresh, live larvae of this species was not recorded before they were placed in ethanol or reared to the adults.

DISCUSSION

At the time of Harrison's (1966) revision of the Australian glow-worms, the genus *Arachnocampa* was included in the Mycetophilidae. Matile (1981) subsequently separated the monophyletic *Arachnocampa* from Mycetophilidae based on seven larval characters, many taken from Edwards (1924), placing them in the family Keroplatidae.

Morphologically, *Arachnocampa* is unusual in that populations of the same species exhibit morphological plasticity depending on their habitat type. Major morphological differences are evident between populations occurring in caves and in nearby epigean habitats (e.g. *A. richardsae*: SNSW1 vs SNSW2) thus making morphological comparisons between these groups detailed and lengthy. An example of this morphological variation is that cave populations display limited pigmentation, if any, along the lateral edges of the larval body (Figs 15B-D, G, H, K, L), whereas the larvae of nearby rainforest populations are generally heavily pigmented down the entire length of the lateral edges of the body (Figs 15A, E, F, J). The darker pigmentation may simply be the result of living in an epigean environment (due to contact with sunlight), and is possibly an adaptation to escape predation as the darker colouration makes them more difficult to see on dark earthy banks and vegetation. Cave-dwelling *Arachnocampa* larvae are lighter and creamier in colouration as they have no contact with pigment altering ultra-violet light (Meyer-Rochow pers. comm.), and pigmentation is

presumably not a necessary adaptation for camouflage in a dark environment. Variation in larval pigmentation between geographically close populations has made morphological identification in the larval stage difficult. Larval descriptions include both cave and epigean colony colouration differences to illustrate this plasticity. The relatively recent availability of some of the man-made 'cave' environments (e.g. mine shafts in Victoria and the Newnes railway tunnel in New South Wales) and the obvious degree of morphological variation between these colonies and nearby epigean colonies strengthens the idea that such characters are plastic within the genus. Cave populations, such as those in Girraween National Park caves (*A. girraweenensis*) and Mt Buffalo cave (*A. buffaloensis*), that now appear entirely restricted to the cave environment may begin to exhibit other troglobitic attributes, as gene-flow from epigean colonies is extremely unlikely. *Arachnocampa buffaloensis* larvae show characteristics (e.g. larval colouration, arrangement of campaniform sensillae on the larval head plate and wings, wing venation) that clearly differentiate them from other mainland Australian *Arachnocampa*. Whether this is a result of their radically different habitat type, or simply chance phenetic mutation remains to be tested.

Other characters that may be important in separating populations are largely variable between cave and rainforest populations. One of these characters, larger body size (mirrored by larger wing and antennal lengths), is evident in all cave dwelling populations and has been suggested to result from a more suitable habitat (Pugsley 1980, 1984) and greater availability of prey (Richards 1960). In southern New South Wales, an artificial cave (a railway tunnel; built between 1906 and 1907 and abandoned in 1912) (NSW National Parks and Wildlife Service 1996) has provided a relatively new habitat for one *A. richardsae* colony (SNSW1). The larvae inhabiting this tunnel exhibit a much larger body size range than nearby rainforest populations (SNSW2-6), again indicating the limited usefulness of size as a character when dealing with organisms adapted to different habitats. A newly constructed limestone replica cave on Tamborine Mountain, Queensland, now contains thousands of *A. flava* originally bred from nearby rainforest gullies. This population now exhibits markedly larger body size after only four years of breeding within the cave system (personal observations).

A correlation has been made between latitude and body size in a number of insect groups (e.g. Muscidae: Alves & Belo 2002; Curculionidae: Chown & Klok 2003; Culicidae: Sota 1994). Epigean glow-worm colonies share very similar body length ranges from north Queensland to New South Wales and as do some in Victoria (see species descriptions for body ranges). However, an increase in body size is evident in cave females, and to a smaller degree, cave males (there are fewer data available for cave males) with increasing latitude, with the largest specimens recorded from caves in Tasmania, Epigean populations near to caves also show larger body sizes, potentially due to breeding with large-bodied cave glow-worms within the same species (e.g. *A. gippslandensis*). This increase in body size may be attributed to decreased temperatures in caves rather than a direct link with latitude. Decreased temperatures increase larval development times, thereby making food resources available for longer periods. This hypothesis has been tested in weevils and correlations were found between relatively aseasonally situated colonies and increased body size (Chown & Klok 2003). As larger caves have a relatively constant temperature due to thermal inertia (de Freitas & Schmekal 2003), this theory may also apply to the large limestone Tasmanian caves occupied by *A. tasmaniensis*. Further studies utilising

morphometric analysis are recommended to identify possible factors driving the observed morphological variations.

All the newly described species share the same basic biological attributes in relation to snare building and maintenance (refer to Baker & Merritt 2003 for description of this behaviour). Differences occur in the length of the snare, but again, this is more likely an artefact of the environment in which they live. Cave environments inhabited by *Arachnocampa* are less exposed to wind turbulence and therefore snares can reach lengths of 20-40 cm without tangling. In contrast, epigean *Arachnocampa* are usually exposed to many weather related factors which combine to ensure snare lengths are short.

The cohabitation of this group in both cave and epigean environments presents an interesting model system for studying the transition of a troglophilic species to a troglobitic species. There have been many theories as to how this transformation occurs (see Holsinger 2000 for a review). For example, some authors believe that founder epigean individuals happen upon subterranean habitat and adapt to this environment. Other theories suggest species exhibit pre-existing characteristics that enable them to flourish in this new environment. If any, the second scenario appears more likely for *Arachnocampa*. For instance, their reliance on a constantly humid environment, their need for darkness to attract prey (with their bioluminescence) and their need for slow air movement for long snare building are examples of how a subterranean environment could provide a particularly suitable habitat. The species are equally adapted to rainforest or cave habitats. However, it is the cave habitat that often provides the prerequisites for colonies to reach very large numbers (i.e. the increase in overhang space for larval snare building).

Living in darkened environments, it is likely that species recognition is based on adult pheromone attraction and therefore future species identification for this genus may involve cuticular hydrocarbon analysis. Population level molecular analysis is recommended to ascertain historical gene flow between populations. In this area, microsatellite analysis may provide useful answers to further species identification in this genus.

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